Waste Water Infrastructure Study

for

Lake Fort Phantom Hill

Prepared for:

CITY OF ABILENE

City of Abilene
Water Administration Department
555 Walnut Street
Abilene, Texas 79601

Prepared by:

Carter::Burgess

STATE OF TEXAS
JERROD MELANDER
98764
LICENSED
PROFESSIONAL ENGINEER

2 OCT 08

September 2008

TABLE OF CONTENTS

List of Tables

List of Exhibits

List of Calculations

List of Cost Calculations

B.1 INTRODUCTION

B.1.1 Purpose

The purpose of this study is to evaluate waste water collection options for residential and commercial development around Lake Fort Phantom Hill in accordance with the 2008 Draft *Lake Fort Phantom Hill Land Use Master Plan* and discussion with staff from the City of Abilene, TX. Results from this evaluation will provide the City of Abilene sufficient information to develop a plan for establishing a waste water collection infrastructure system around Lake Fort Phantom Hill. Upon selecting an option, financing, waste water master planning, design, and construction of the Lake Fort Phantom Hill waste water infrastructure system can be developed to serve the projected population and commercial growth around the Lake.

B.1.2 Scope of Work

The scope of work for this study includes:

- Evaluation of waste water collection infrastructure system options for two (2) conveyance scenarios around Lake Fort Phantom Hill.
- Provide estimated cost data for each waste water collection option.

This study evaluates major components of a waste water collection system and does not include all components internal to a development area. The internal components would be determined for each development area based upon the specific layout and configuration of that development area. Evaluation of the treatment system for the waste water is beyond the scope of this report. The average and design flows are based on the each sections estimated population or living unit equivalent.

B.1.3 Abbreviations

Abbreviation	Definition
BCLS	Buck Creek Lift Station
CCS	Central Collection System
EGL	Energy Grade Line
EPA	Environmental Protection Agency
gpcd	Gallons per capita per day
gpm	Gallons per minute
gpd	Gallons per day
LPS	Low Pressure Sewer
LUE	Living Unit Equivalent
MG	Million Gallons
MGD	Million gallons per day
OSSF	On-site sewage facilities (septic tank systems)

STEP	Septic Tank Effluent Pump
TCEQ	Texas Commission on Environmental Quality
TWDB	Texas Water Development Board
WWTP	Waste Water Treatment Plant

B.2 SCENARIOS AND OPTIONS

B.2.1 Scenarios

Jacobs Carter Burgess, in conjunction with the City of Abilene, established a conceptual plan for residential and commercial development for Lake Fort Phantom Hill. The two (2) conveyance scenarios resulting from the conceptual plan evaluate the feasibility and cost associated with providing sanitary sewer infrastructure to specific locations within the development. The scenarios have individual exhibits that clarify the following descriptions.

B.2.1.1 Scenario 1: East Side Only

The East Side Only conveyance scenario evaluates providing a central sanitary sewer collection system to only the east side of Lake Fort Phantom Hill. The remainder of the lake (west side) will utilize OSSF. In this scenario 5,003 LUEs with and equivalent population of 12,507 will be connected to the central sanitary collection system and 3,503 LUEs and an equivalent population of 8,759 will utilize OSSF. See Exhibits 1A and 1B for the Scenario 1 infrastructure schematic.

B.2.1.2 Scenario 2: East Side and Partial West Side

The East and Southern West Side conveyance scenario evaluates providing a central sanitary collection system to the east side and Lake Residential sections 11, 12, and 13 on the southern west side. The remainder of the west side will utilize OSSF. In this scenario 5,665 LUEs with a population equivalent of 14,162 will be connected to the central sanitary sewer collection system and 2,841 LUEs and a population equivalent of 7,104 will utilize OSSF. See Exhibit 3 for the Scenario 2 infrastructure schematic.

Table B-1 Scenario Population Summary

Scenario	Central Sanitary Collection System	On Site Sewer Facilities	Total Equivalent Population
East Side Only	12,507	8,759	21,266
East Side and Partial West Side	14,162	7,104	21,266

B.2.2 Options

Two (2) central collection system options were investigated for each scenario: a traditional gravity system and a low pressure system. The reason for evaluating multiple options stems from the undulating terrain around the lake. A discussion of each option and the effects of terrain on its functionality/feasibility are below. In either case, the waste water will be collected and conveyed to a new lift station and then pumped to either the Buck Creek Lift Station or Hamby WWTP.

B.2.2.1 Traditional Gravity System

The traditional gravity sewer system utilizes gravity to convey the waste water from the source (home, business, etc…) to the collection lines. In order to obtain a velocity of 2 ft/s, as required by TCEQ proposed Chapter 217 and Chapter 317 *Design Criteria for Sewerage Systems*, certain pipe slopes are necessary to allow the wastewater to flow downhill. Because of the slope criteria, gravity systems have the potential to be very deep and use pipes with larger diameters. In order to minimize pipe depths, lift stations can be utilized. The lift stations pump the waste water through a force main to an elevation at which gravity flow is once again feasible. Calculations for gravity system design flows in the context of this study use the Harmon Peaking Factor formula and the velocity is based on Manning's equation. Few alignment and system options exist for use of a gravity system around Lake Fort Phantom Hill, based on the terrain.

B.2.2.2 Low Pressure System

Low pressure systems utilize a pump to convey the waste water to either a gravity system or to the treatment works, essentially a system of many small lift stations. Two (2) types of low pressure systems are currently in practice. The first system, grinder pump, takes waste water flows from the source (home, business, etc…), grinds it into slurry and pumps the slurry into a pressurized pipe system which conveys the slurry to either a gravity system or to the treatment works. The second system, STEP, utilizes a septic tank to settle the solids and then an effluent pump to send the liquid effluent to a pressurized line conveying it to a gravity system or to the treatment works. A STEP system eliminates the need for a drain field commonly found with conventional septic tank systems, but still requires some form of septic tank maintenance, including cleaning and/or removal of sludge. The STEP system would be a viable option with converting the existing septic systems only. All new systems would be built using grinder pumps. In utilizing low pressure systems, pipe slope is not a guiding factor, therefore, line diameters tend to be smaller than gravity systems and depths can be relatively shallow, typically just below the frost line. Calculations for low pressure design flows in context of this study use the EPA's Q=AN+B formula and the Hazen-Williams equation for velocity. Additional information on these formulas and low pressure systems in general are found in the EPA's Manual for Alternative Wastewater Collection Systems, EPA/625/1-91/024, dated October 1991. Proposed TCEQ Chapter 217, Section 217.97 will govern the design of pressure sewers in Texas, and therefore, has been utilized in this analysis. Proposed Chapter 217 requires the use of the Hazen-Williams equation and a C factor of 120.

The options involving low pressure systems look at two possible configurations, individual grinder pump system and clustered grinder pump systems. The individual grinder pump system would provide a grinder pump at each home or business which would pump directly into the pressure collection mains. Whereas the clustered system would consolidate waste water from a group of homes or business into a wet well or tank and pump to the collection mains via grinder pumps. In the clustered system at least two (2) grinder pumps are required to account for redundancy. In either case the infrastructure from the pumps to the consolidated lift station will remain the same.

B.2.3 Water Quality and Maintenance

Each option has potential impacts to the Lake's water quality. The traditional gravity system has potential for sewage to infiltrate into the ground water through improperly sealed connections at manholes, or during high rainfall events, or from pipe failure. Low pressure systems can cause water quality issues if a grinder pump fails or if pipes fail. In the clustered option, the holding tanks are a potential groundwater infiltration hazard, especially if proper maintenance does not occur. Additionally, the tanks in the clustered option pose a potential for odor problems and proper mitigating steps would need to take place. Many of these issues would occur if there was a lack of proper maintenance. TCEQ proposed Chapter 217, Sections 217.94 and 217.95 discuss the management structure and service agreements associated with low pressure systems (subset of alternative systems). In these sections it states that the property owner may be tasked with maintenance of the on-site components, but the management/operator entity has overall responsibility of the system, including the on-site components. The actual maintenance division of responsibility can be laid out in the Sewer Service Agreement.

B.3 GENERATED WASTE WATER FLOWS

B.3.1 Existing

In 2005, Carter & Burgess, Inc. conducted a Water Quality Study for Lake Fort Phantom Hill in which the existing waste water systems were evaluated. The current method of waste water handling for the existing 438 dwelling units is via OSSF, or septic systems. These septic systems utilize a septic tank and a drainfield. As the existing homes are spread out around the perimeter of the lake, their septic systems would need to be modified relative to the decided upon collection system method. During that study a 300 gpd usage rate per dwelling was assumed, making the total waste water flow 131,400 gpd. During construction of the new system, the existing homes will be either redeveloped or converted to the new system.

B.3.2 Projected

Utilizing development factors of 2.5 people per LUE from the *Lake Fort Phantom Hill Land Use Master Plan* and average load per person of 100 gpcd from TCEQ Chapter 217 Section 217.32, the average and peak waste water flows were determined for each scenario. A list of LUE assumptions is located in Calculation Table 1 and on each subsequent calculation table. As mentioned in each of the options the design flows were calculated using either the Harmon Peaking Factor for the gravity system or the EPA's formula for the LPS. For the LPS, design flows remain the same whether it is an individual system or clustered system. The following table summarizes the design flows for each scenario and option. For purposes of design the higher value should be used.

Table B-2 Scenario Design Waste Water Flow Summary

Scenario	CCS Equivalent Population	CCS Peak Flow (gpm)		OSSF Equivalent Population	OSSF Peak Flow (gpm)
		Harmon Flow	EPA Flow		
East Side Only	12,507	3,241	3,402	8,759	2,257
East Side and Partial West Side	14,162	3,693	3,859	7,102	1,805

B.4 EVALUATION OF SCENARIOS AND OPTIONS

B.4.1 Scenario 1: East Side Only

B.4.1.1 Option A: Traditional Gravity

The range of elevations on the east side of the lake vary greatly along the coast line, making the use of a traditional gravity collection system difficult. For this reason, approximately seven (7) lift stations will be required to convey the waste to the WWTP. Starting on the north shore with Lake Residential 9, the smallest lift station will need a capacity of 0.36 MGD. The largest lift station will need a capacity of 4.67 MGD and will be located near the intersection of East Phantom Hill Road and CR-306. The locations and capacities of the remaining lift stations are shown on Exhibit 2a. Flows from the each LUE will be conveyed via gravity to the main line running along East Phantom Hill Rd. Once in the main trunk line the sewer flows will be conveyed to the WWTP via gravity and force main. The pipe sizes for the gravity lines range from 6 inches to 15 inches. The force mains exiting the lift stations also range from 4 inches to 15 inches. See Exhibit 1A for the schematic of the East Side Gravity System. The estimated cost for the east side gravity system is $25.5M or $5,100 per LUE.

B.4.1.2 Option B: Pressure System

The LPS will be aligned similar to the gravity system; however, since the all the lines will be pressurized, the need for lift stations goes away. The only lift station to remain is the lift station to send the waste water to either the BCLS or the Hamby WWTP. Line sizes for the LPS range from 2 inches to 15 inches. See Exhibit 1B for the schematic of the East Side Pressure System. The estimated cost for the east side individual pressure system is $36.6M or $7,300 per LUE. The estimated cost for the east side cluster pressure system is $39.5M or $7,900 per LUE.

B.4.1.3 West Side OSSF Configurations

For both Scenarios 1A and 1B, the west side will utilize OSSF. Two configurations exist for the OSSF, individual and cluster. The individual system will consist of a traditional septic tank, pump, evapotranspiration bed, and associated materials. A thorough site investigation to determine soils and layout should be completed before installation of the septic systems. The estimated cost for the west side individual OSSF system is $25.9M or $7,400 per LUE.

The cluster OSSF configuration will consist of the following: sixteen (16) LUE, four (4) 1,500 gallon pre-cast tanks, one (1) effluent storage tank and pumps (3 days detention), sand and gravel, and one (1) evapotranspiration bed and associated piping and equipment. Exact configuration of the OSSF is beyond the scope of this infrastructure study and can be determined during future design of the development areas on the west side. Additionally, maintenance for the clustered OSSF configuration would be the responsibility of the City of Abeline. The estimated cost for the west side cluster OSSF system is $58.0M or $16,600 per LUE.

B.4.2 Scenario 2: East Side and Partial West Side

In Scenario 2: East Side and Partial West Side, introduces the two sanitary sewer options to portions of the west side. The portions selected for sewer in Scenario 2 are Lake Residential 11, 12, and 13. The remaining areas of the west side will utilize OSSF, either individual or cluster systems. In the instance where additional development on the west side requests to be included on the central collection system, the pipe sizes and alignments will need to be reevaluated. The infrastructure on the east side will remain as in the Scenario 1 options.

B.4.2.1 Option A: Traditional Gravity

In order to gain the maximum use of gravity, the alignment of the main line for the west side partial gravity option, must stay along the shoreline of the lake. Starting in Lake Residential 11 and ending at a lift station in Lake Residential 13, the gravity main would need to be at least an 8-inch pipe with a 0.34% slope. At Lake Residential 13 an additional lift station (capacity: 0.65 MGD) would pump the sewage to the southernmost lift station on the east side via a 6-inch force main. See Exhibit 2A for the schematic of the East Side and Partial West Side Gravity System. The estimated cost for the a gravity system for Lake Residential 11, 12, and 13, and individual OSSF for the remaining west side is $25.7M or an average of $7,300 per LUE. The estimated cost for the gravity system for Lake Residential 11, 12, and

13, and cluster OSSF for the remaining west side is $51.7M or an average of $14,800 per LUE.

B.4.2.2 Option B: Pressure System

Using a pressure system on the west side reduces the restrictions on alignment since gravity is not a factor and elevation differences can be overcome by selecting the appropriate grinder pumps. As in Scenario 1B, two (2) configurations exist for the pressure system for Lake Residential 11, 12, and 13 on the west side, individual or cluster. For either configuration, the pressure line conveying the sewage from the west side to the east side will need to be a minimum of 6-inches. The pressure line will terminate at the lift station located in the vicinity of East Phantom Hill Rd and CR-306. With the pressure system on the west side four (4) combinations are available: 1) Individual Partial Pressure, Individual OSSF; 2) Individual Partial Pressure, Cluster OSSF; 3) Cluster Partial Pressure, Individual OSSF; and 4) Cluster Partial Pressure, Cluster OSSF. See Exhibit 2B for the schematic of the East Side and Partial West Side Pressure System. The estimated cost for combination 1) Individual pressure for Lake Residential 11, 12, and 13, and individual OSSF for the remaining west side is $26.4M or an average of $7,500 per LUE. The estimated cost for combination 2) Individual pressure for Lake Residential 11, 12, and 13, and cluster OSSF for the remaining west side is $52.5M or an average of $15,000 per LUE. The estimated cost for combination 3) Cluster pressure for Lake Residential 11, 12, and 13, and individual OSSF for the remaining west side is $27.2M or an average of $7,800 per LUE. The estimated cost for combination 4) Cluster pressure for Lake Residential 11, 12, and 13, and cluster OSSF for the remaining west side is $53.3M or an average of $15,200 per LUE.

B.5 SUMMARY OF ESTIMATED COST

Since there are several combinations of options and configurations that can be selected, the following tables show the possible combinations, cost per LUE by system type, total combined cost, and average cost per LUE. The tables are presented in order of Scenario.

B.5.1 Scenario 1

The most cost effective option and configuration combination for Scenario 1 is the East Side Gravity option and the West Side Individual OSSF configuration. The average cost per LUE is approximately $6,050. See Table B-3 for the remaining combination costs. Itemized cost lists are located in Cost Calculation Sheets 1 through 5.

Table B-3 Scenario 1 Option and Configuration Cost Summary

Scenario	Option and Configuration	Cost per LUE $	Total Cost $	Average Cost per LUE $
Scenario 1A	East Side - Gravity	5,100	51.4M	6,050
	West Side – OSSF (Individual)	7,400		
	East Side - Gravity	5,100	83.5M	9,800
	West Side – OSSF (Cluster)	16,600		
Scenario 1B	East Side – Pressure (Individual)	7,300	62.5M	7,350
	West Side – OSSF (Individual)	7,400		
	East Side – Pressure (Individual)	7,300	94.6M	11,100
	West Side – OSSF (Cluster)	16,600		
	East Side – Pressure (Cluster)	7,900	65.4M	7,700
	West Side – OSSF (Individual)	7,400		
	East Side – Pressure (Cluster)	7,900	97.5M	11,500
	West Side – OSSF (Cluster)	16,600		

*These estimates do not include the upgrades to the Hamby WWTP, upgrades to the BCLS, and associated piping.

B.5.2 Scenario 2

The most cost effective option and configuration combination for Scenario 2 is the East Side Gravity option and the West Side Partial Gravity and Partial Individual OSSF configuration. The average cost per LUE is approximately $6,000. See Table B-4 for the remaining combination costs. Itemized cost lists are located in Cost Calculation Sheets 1 through 5.

Table B-4 Scenario 2 Option and Configuration Cost Summary

Scenario	Option and Configuration	Cost per LUE $	Total Cost $	Average Cost per LUE $
Scenario 2A	East Side - Gravity	5,100	51.1M	6,000
	West Side – Partial Gravity	7,000		
	West Side – Partial OSSF (Individual)	7,400		
	East Side - Gravity	5,100	77.2M	9,100
	West Side – Partial Gravity	7,000		
	West Side – Partial OSSF (Cluster)	16,600		
Scenario 2B	East Side – Pressure (Individual)	7,300	63.0M	7,400
	West Side – Partial Pressure (Individual)	8,200		
	West Side Partial OSSF (Individual)	7,400		
	East Side – Pressure (Individual)	7,300	63.8M	7,500
	West Side – Partial Pressure (Cluster)	9,400		
	West Side Partial OSSF (Individual)	7,400		
	East Side – Pressure (Individual)	7,300	89.9M	10,600
	West Side – Partial Pressure (Cluster)	9,400		
	West Side Partial OSSF (Cluster)	16,600		
	East Side – Pressure (Cluster)	7,900	65.9M	7,750
	West Side – Partial Pressure (Individual)	8,200		
	West Side Partial OSSF (Cluster)	7,400		
	East Side – Pressure (Cluster)	7,900	66.7M	7,850
	West Side – Partial Pressure (Cluster)	9,400		
	West Side Partial OSSF (Individual)	7,400		
	East Side – Pressure (Cluster)	7,900	92.8M	10,900
	West Side – Partial Pressure (Cluster)	9,400		
	West Side Partial OSSF (Cluster)	16,600		

*These estimates do not include the upgrades to the Hamby WWTP, upgrades to the BCLS, and associated piping.

B.6 CONCLUSION/SUMMARY

Several options and configurations exist for waste water infrastructure for development around Lake Fort Phantom Hill. The estimated costs provided are based on approximate figures provided by the Lake Fort Phantom Hill Land Use Plan and LUE assumptions. Further investigation, such as detailed survey and soils analysis must be performed in order to determine the applicability of certain options and configurations in this study. Maintenance costs options for central collection systems and clustered OSSF are outside the scope of this study and can be discussed upon option and configuration selection. Final cost per lot can be realized upon the layout of each development area. The lot configuration will determine the internal development piping and associated cost. Additional cost will accrue as upgrades to the BCLS and Hamby WWTP occur and should be included in the complete evaluation of development feasibility. Transmission mains to either BCLS or Hamby WWTP will be in the $5M order of magnitude. Upgrades to the BCLS, if sent there, and the Hamby WWTP are estimated to be in the order of $15M to $20M. Selection of the final system configuration should be based on the demonstrated demand and development patterns for residence around Lake Fort Phantom Hill.

Calculation 1: Development Factors and LUE Count

*Use activity and sewer load or LUEs assumptions					
Residential	Single Family			1 LUE per unit	
Mulit-Family	Apartments			.7 LUE per unit	
Comm Rec 1	Fun Town/Grill	2 toilets		1 LUE per 4 toilets	0.5
	Fishing/Bait/Rentals				
	Public Rest Room	4 toilets		1 LUE per 4 toilets	1
Comm Rec 2	Retail	5,000 sf retail space		1 LUE per 4,500 sf	1
	Hotel/Lodge	100 rooms		1 LUE per 4 rooms	25
	Restaurants	8,000 sf		1 LUE per 166 sf	48
	Public Rest Room	6 toilets		1 LUE per 4 toilets	2
	Camping	50 spaces	6 Toilets	1 LUE per 4 toilets	2
	RV	50 spaces		1 LUE per 4 vehicles	13
Comm Rec 3	Recreation equip rentals				
	Boat Launch/Docks				
	Public Rest Room	6 toilets		1 LUE per 4 toilets	2
	Camping	50 spaces	6 Toilets	1 LUE per 4 toilets	2
	RV	50 spaces		1 LUE per 4 vehicles	13
Comm Rec 4	Resort Lodge	150 rooms		1 LUE per 4 rooms	38
	Resort cabins	30 cabins		1 LUE per unit	30
	Motel	100 rooms		1 LUE per 4 rooms	25
	Restaurant	8,000 sf		1 LUE per 166 sf	48
					248
Park 1	Camping	50 spaces	12 Toilets	1 LUE per 4 toilets	3
	Boat Launch/Docks				
Park 2	Boat Launch/Docks				
Park 3	Camping	200 spaces	24 Toilets	1 LUE per 4 toilets	6
Park 4	Picnic/Day Use				
	Public Rest Room	4 toilets		1 LUE per 4 toilets	1
Park 5	Picnic/Day Use				
	Public Rest Room	4 toilets		1 LUE per 4 toilets	1
Park 6	Camping	50 spaces	8 Toilets	1 LUE per 4 toilets	2
	RV	100 spaces		1 LUE per 4 vehicles	25
	Boat Launch/Docks				
	Public Rest Room	8 toilets		1 LUE per 4 toilets	2
Park 7	Boat Launch/Docks				
	Public Rest Room	8 toilets		1 LUE per 4 toilets	2
Park 8	Public Rest Room	2 toilets		1 LUE per 4 toilets	0.50
					43
Marina 1	Sales/Service/Storage/Launch	2 toilets		1 LUE per 4 toilets	0.50
Marina 2	Sales/Service/Storage/Launch	2 toilets		1 LUE per 4 toilets	0.50
					1
Total LUEs for Park, Commercial Recreation Activities					290

Calculation 2: East Side Sanitary Sewer
(Gravity System)

Legend Location (North to South)	LUE	Population or Population Equivalent P	Avg Rate of Flow Q (gpm)	Harmon Peaking Factor M	Design Q (gpm)	Peak Design / Required Flow (MGD)	Trial Pipe Diameter (in)	A (ft^2)	Hydraulic Radius r_h	Slope (%)	V (ft/s)	provided (gpm)	provided (MGD)	Gravity (G), FM (F), Septic (S), Pressure (P)	Force Main Pipe Diameter (in)	Force Main Velocity (fps)
Lake Residential 9	376	940	65.24	3.82	249.02	0.36	6	0.20	0.125	1.000	2.84	250.08	0.36	G	N/A	N/A
Section Total	376	940	65.24		249.02	0.36	6	0.20	0.125	1.000	2.84	250.08	0.36	F	4	6.36
View Residential 1	280	700	48.58	3.89	189.20	0.27	6	0.20	0.125	0.580	2.16	190.46	0.27	G	N/A	N/A
Lake Residential 8	176	440	30.54	4.00	122.21	0.18	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Park 3	10	25	1.74	4.37	7.58	0.01	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Section Total	466	1165	80.85		318.98	0.46	8	0.35	0.167	0.355	2.05	321.21	0.46	G	N/A	N/A
Runing Total	842	2105	146.09		568.00	0.82	8	0.35	0.167	1.130	3.66	573.08	0.83	F	6	6.45
Lake Residential 7	66	165	11.45	4.18	47.83	0.07	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
View Residential 2	56	140	9.72	4.20	40.81	0.06	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Section Total	122	305	21.17		88.65	0.13	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Running Total	964	2410	167.25		656.65	0.95	10	0.55	0.208	0.455	2.70	659.82	0.95	F	6	7.45
Lake Residential 6	556	1390	96.47	3.70	357.24	0.51	8	0.35	0.167	0.440	2.28	357.60	0.51	G	N/A	N/A
Section Total	556	1390	96.47		357.24	0.51	8	0.35	0.167	0.440	2.28	357.60	0.51	G	N/A	N/A
Running Total	1520	3800	263.72		1013.88	1.46	10	0.55	0.208	1.080	4.15	1016.56	1.46	F	8	6.47
View Residential 3	66	165	11.45	4.18	47.83	0.07	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Lake Residential 5	178	445	30.88	4.00	123.52	0.18	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Multi Use 1	1230	3075	213.41	3.43	732.68	1.06	10	0.55	0.208	0.360	2.40	586.91	0.85	G	N/A	N/A
Lake Residential 4	304	760	52.74	3.87	204.31	0.29	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Section Total	1778	4445	308.48		1108.35	1.60	12	0.79	0.250	0.500	3.19	1125.44	1.62	G	N/A	N/A
Running Total	3298	8245	572.20		2122.23	3.06	15	1.23	0.312	0.550	3.89	2141.75	3.08	F	12	6.02
Lake Residential 3	184	460	31.92	3.99	127.46	0.18	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
View Residential 4	94	235	16.31	4.12	67.22	0.10	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Marina 1	0.5	1.25	0.09	4.47	0.39	0.00	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Section Total	278.5	696.25	48.32		195.07	0.28	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Running Total	3576.5	8941.25	620.52		2317.30	3.34	15	1.23	0.312	0.650	4.23	2328.32	3.35	F	12	6.57
Park 1	3	7.5	0.52	4.43	2.30	0.00	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Park 2	15	37.5	2.60	4.34	11.29	0.02	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Lake Residential 2	217	542.5	37.65	3.96	148.93	0.21	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Section Total	235	587.5	40.77		162.53	0.23	8	0.35	0.167	0.465	2.35	367.62	0.53	G	N/A	N/A
East Side Total	3811.5	9528.75	661.30		2479.83	3.57	15	1.23	0.312	0.750	4.54	2501.02	3.60	F	12	7.03
View Residential 5	660	1650	114.51	3.65	417.88	0.60	8	0.35	0.167	0.330	1.98	309.69	0.45	G	N/A	N/A
Commercial Recreation 1	1.5	3.75	0.26	4.45	1.16	0.00	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Lake Residential 1	530	1325	91.96	3.72	341.88	0.49	8	0.35	0.167	0.450	2.31	361.64	0.52	G	N/A	N/A
Section Total	1191.5	2978.75	206.73		760.91	1.10	8	0.35	0.167	0.465	2.35	367.62	0.53	G	N/A	N/A
East Side Total	5003.0	12507.5	868.02		3240.74	4.67	15	1.23	0.312	1.260	5.89	3241.69	4.67	F	15	5.88

Assumptions:

		LUE
Dwelling Units per Acre		
	Residential Single Family	1
	Multi-Family	0.7
People per Living Unit Equivalent =		2.5
Avg Load per person (gpm)		0.0694
Gallons per person per day =		100

Harmon Peaking Factor:

$$M = 1 + \frac{14}{4 + \sqrt{P}}$$

P = Population in 1000

Manning's Equation:

$$V = \frac{1.49}{n} \left(r_h^{0.67}\right) S^{0.5}$$

n = 0.013

Notes:
1) All sewage will be sent to the Buck Creek Lift Station or the Hamby Waste Water Treatment Plant
2) All other proposed sewers not shown will be 6-inch lines at slopes of 0.5% or greater.
3) Pipe slopes will not exceed the maximum slope specified for the diameter in accordance with TNRCC Chapter 317 Requirements
4) All velocities exceed the minimum 2 fps criteria.
5) Infiltration and Inflow is not considered since it is new construction.
6) Harmon Peaking Factor is used to determine Peak Dry Design Flow

Calculation 3: East Side Sanitary Sewer
(Low Pressure System)

Legend Location (North to South)	LUE	Population or Population Equivalent P	Avg Rate of Flow Q (gpm)	Design Q (gpm)	Peak Design / Required Flow (MGD)	Trial Pipe Diameter (in)	A (ft^2)	V (ft/s)	Hydraulic Radius r_h	S_{hg}	Gravity (G), FM (F), Septic (S), Pressure (P)	Pressure Pipe Diameter (in)	Pressure Pipe Velocity (fps)
Lake Residential 9	376	940	65.24	245.60	0.35	4	0.09	6.28	0.083	0.046	P	4	6.27
Section Total	376	940	65.24	245.60	0.35	4	0.09	6.28	0.083	0.046	P	4	6.27
View Residential 1	280	700	48.58	188.00	0.27	4	0.09	4.81	0.083	0.028	P	4	4.80
Lake Residential 8	176	440	30.54	125.60	0.18	4	0.09	3.21	0.083	0.013	P	4	3.21
Park 3	10	25	1.74	26.00	0.04	2	0.02	2.66	0.042	0.021	P	2	2.66
Section Total	466	1165	80.85	339.60	0.49	4	0.09	8.69	0.042	0.189	P	4	8.67
Runing Total	842	2105	146.09	585.20	0.84	6	0.20	6.65	0.125	0.032	P	6	6.64
Lake Residential 7	66	165	11.45	59.60	0.09	2	0.02	6.10	0.042	0.098	P	2	6.09
View Residential 2	56	140	9.72	53.60	0.08	2	0.02	5.48	0.042	0.081	P	2	5.47
Section Total	122	305	21.17	113.20	0.16	4	0.09	2.90	0.042	0.025	P	4	2.89
Running Total	964	2410	167.25	698.40	1.01	6	0.20	7.94	0.125	0.045	P	8	4.46
Lake Residential 6	556	1390	96.47	353.60	0.51	6	0.20	4.02	0.125	0.013	P	6	4.01
Section Total	556	1390	96.47	353.60	0.51	6	0.20	4.02	0.125	0.013	P	6	4.01
Running Total	1520	3800	263.72	1052.00	1.51	8	0.35	6.73	0.167	0.023	P	8	6.71
View Residential 3	66	165	11.45	59.60	0.09	2	0.02	6.10	0.042	0.098	P	2	6.09
Lake Residential 5	178	445	30.88	126.80	0.18	4	0.09	3.24	0.083	0.014	P	4	3.24
Multi Use 1	1230	3075	213.41	758.00	1.09	8	0.35	4.85	0.167	0.013	P	8	4.84
Lake Residential 4	304	760	52.74	202.40	0.29	4	0.09	5.18	0.083	0.032	P	4	5.17
Section Total	1778	4445	308.48	1146.80	1.65	10	0.55	4.69	0.083	0.027	P	10	4.68
Running Total	3298	8245	572.20	2198.80	3.17	10	0.55	9.00	0.208	0.031	P	12	6.24
Lake Residential 3	184	460	31.92	130.40	0.19	4	0.09	3.34	0.083	0.014	P	4	3.33
View Residential 4	94	235	16.31	76.40	0.11	2	0.02	7.82	0.042	0.156	P	2	7.80
Marina 1	0.5	1.25	0.09	20.30	0.03	2	0.02	2.08	0.042	0.013	P	2	2.07
Section Total	278.5	696.25	48.32	227.10	0.33	4	0.09	5.81	0.042	0.090	P	4	5.80
Running Total	3576.5	8941.25	620.52	2425.90	3.49	10	0.55	9.93	0.208	0.037	P	12	6.88
Park 1	3	7.5	0.52	21.80	0.03	4	0.09	0.56	0.083	0.001	P	2	2.23
Park 2	15	37.5	2.60	29.00	0.04	4	0.09	0.74	0.083	0.001	P	2	2.96
Lake Residential 2	217	542.5	37.65	150.20	0.22	4	0.09	3.84	0.083	0.019	P	4	3.83
Section Total	235	587.5	40.77	201.00	0.29	8	0.35	1.29	0.083	0.002	P	8	1.28
East Side Total	3811.5	9528.75	661.30	2626.90	3.78	15	1.23	4.78	0.313	0.006	P	15	4.77
View Residential 5	660	1650	114.51	416.00	0.60	6	0.20	4.73	0.125	0.017	P	6	4.72
Commercial Recreation 1	1.5	3.75	0.26	20.90	0.03	4	0.09	0.53	0.083	0.000	P	2	2.13
Lake Residential 1	530	1325	91.96	338.00	0.49	6	0.20	3.84	0.125	0.012	P	6	3.84
Section Total	1191.5	2978.75	206.73	774.90	1.12	8	0.35	4.96	0.125	0.019	P	8	4.95
East Side Total	5003.0	12507.5	868.02	3401.80	4.90	15	1.23	6.19	0.313	0.010	P	15	6.18

Assumptions:

		LUE
Dwelling Units per Acre		
	Residential Single Family	1
	Multi-Family	0.7
People per Living Unit Equivalent =		2.5
Avg Load per person (gpm)		0.0694
Gallons per person per day =		100

EPA Formula:

Design Flow: Q=AN+B
Coeff A = 0.60
Factor B = 20
N = The number of LUE

Hazen -Williams Equation:

$$V = 1.318\, C \left(r_h^{0.63}\right) S_{hg}^{0.54}$$

C= 120
Est LUE per Cluster = 5

Notes:

1) All sewage will be sent to the Buck Creek Lift Station or the Hamby Waste Water Treatment Plant
2) All other proposed sewers not shown will be 6-inch lines at slopes of 0.5% or greater.
3) Pipe slopes will not exceed the maximum slope specified for the diameter in accordance with TNRCC Chapter 317 Requirements
4) All velocities exceed the minimum 2 fps criteria.
5) Infiltration and Inflow is not considered since it is new construction.
6) EPA fromulas obtained from the EPA's Alternative Wastewater Collection Systems Manual (EPA/625/1-91/024 dated October 1991)

Calculation 4: West Side Sanitary Sewer
Scenario 1(All Septic)

Legend Location (North to South)	LUE	Population or Population Equivalent P	Avg Rate of Flow Q (gpm)	Harmon Peaking Factor M	Design Q (gpm)	Peak Design / Required Flow (MGD)	Trial Pipe Diameter (in)	A (ft^2)	Hydraulic Radius r_h	Slope (%)	V (ft/s)	provided (gpm)	provided (MGD)	Gravity (G), FM (F), Septic (S), Pressure (P)	Number of ET Beds	Number of Precast Tanks
Johnson Park	50	125	8.68	4.22	36.57	0.05	6	0.20	0.125	0.500	2.01	176.84	0.25	S	4	16
Park 4	1	2.5	0.17	4.46	0.77	0.00	6	0.20	0.125	0.500	2.01	176.84	0.25	S	1	1
Section Total	51	127.5	8.85		37.35	0.05								S	5	17
Marina 2	0.5	1.25	0.09	4.47	0.39	0.00	6	0.20	0.125	0.500	2.01	176.84	0.25	S	1	1
Lake Residential 10	202	505	35.05	3.97	139.21	0.20	6	0.20	0.125	0.500	2.01	176.84	0.25	S	13	52
Section Total	202.5	506.25	35.13		139.59	0.20								S	14	53
Runing Total	253.5	633.75	43.98		176.94	0.25								S	19	70
Commercial Recreation 2	16	40	2.78	4.33	12.03	0.02	6	0.20	0.125	0.500	2.01	176.84	0.25	S	1	4
Section Total	16	40	2.78		12.03	0.02								S	1	4
Running Total	269.5	673.75	46.76		188.97	0.27								S	20	74
Lake Residential 11	136	340	23.60	4.05	95.67	0.14	6	0.20	0.125	0.500	2.01	176.84	0.25	S	9	36
Lake Residential 12	282	705	48.93	3.89	190.46	0.27	6	0.20	0.125	0.600	2.20	193.71	0.28	S	18	72
Lake Residential 13	244	610	42.33	3.93	166.30	0.24	6	0.20	0.125	0.500	2.01	176.84	0.25	S	16	64
Commercial Recreation 3	100	250	17.35	4.11	71.33	0.10	6	0.20	0.125	0.500	2.01	176.84	0.25	S	7	28
Sea Bee/Dyess Park	50	125	8.68	4.22	36.57	0.05	6	0.20	0.125	0.500	2.01	176.84	0.25	S	4	16
Section Total	812	2030	140.88		560.33	0.81								S	54	216
Running Total	1081.5	2703.75	187.64		749.30	1.08								S	74	290
Rural 1	1185	2962.5	205.60	3.45	708.70	1.02	10	0.55	0.208	0.520	2.88	705.38	1.02	S	75	300
Rural 2	9	22.5	1.56	4.37	6.83	0.01	6	0.20	0.125	0.500	2.01	176.84	0.25	S	1	2
Rural 3	682	1705	118.33	3.64	430.55	0.62	8	0.35	0.167	0.630	2.73	427.90	0.62	S	43	172
Rural 4	89	222.5	15.44	4.13	63.79	0.09	6	0.20	0.125	0.500	2.01	176.84	0.25	S	6	24
Rural 5	457	1142.5	79.29	3.76	298.28	0.43	6	0.20	0.125	1.500	3.48	306.29	0.44	S	29	116
Section Total	2422	6055	420.22		1508.15	2.17								S	154	614
West Side Total	3503.5	8758.75	607.86		2257.45	3.25								S	228	904

Assumptions:

		LUE
Dwelling Units per Acre		
	Residential Single Family	1
	Multi-Family	0.7
People per Living Unit Equivalent =		2.5
Avg Load per person (gpm)		0.0694
Gallons per person per day =		100
Dwelling Units per Septic Cluster =		16
Prescast Tanks per Septic Cluster =		4

Harmon Peaking Factor:

$$M = 1 + \frac{14}{4 + \sqrt{P}}$$

P = Population in 1000

Manning's Equation:

$$V = \frac{1.49}{n} \left(r_h^{0.67}\right) S^{0.5}$$

n = 0.013

Notes:

1) All sewage will be sent to the Buck Creek Lift Station or the Hamby Waste Water Treatment Plant
2) All other proposed sewers not shown will be 6-inch lines at slopes of 0.5% or greater.
3) Pipe slopes will not exceed the maximum slope specified for the diameter in accordance with TNRCC Chapter 317 Requirements
4) All velocities exceed the minimum 2 fps criteria.
5) Infiltration and Inflow is not considered since it is new construction.
6) Harmon Peaking Factor is used to determine Peak Dry Design Flow

Legend Location (North to South)	LUE	Population or Population Equivalent P	Avg Rate of Flow Q (gpm)	Harmon Peaking Factor M	Design Q (gpm)	Peak Design / Required Flow (MGD)	Trial Pipe Diameter (in)	A (ft^2)	Hydraulic Radius r_h	Slope (%)	V (ft/s)	provided (gpm)	provided (MGD)	Gravity (G), FM (F), Septic (S), Pressure (P)	Force Main Pipe Diameter (in)	Force Main Velocity (fps)
Central Sanitary Sewer Collection System																
Lake Residential 11	136	340	23.60	4.05	95.67	0.14	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
Lake Residential 12	282	705	48.93	3.89	190.46	0.27	6	0.20	0.125	0.600	2.20	193.71	0.28	G	N/A	N/A
Section Total	418	1045	72.52		286.14	0.41	8	0.35	0.167	0.340	2.01	314.35	0.45	G	N/A	N/A
Lake Residential 13	244	610	42.33	3.93	166.30	0.24	6	0.20	0.125	0.500	2.01	176.84	0.25	G	N/A	N/A
West Side CCS Total	662	1655	114.86		452.43	0.65								F	6	5.13
Total In Gravity System	**5665**	**14162.5**	**982.88**		**3693.17**	**5.32**								**F**	**15**	**6.71**
On-Site Sewer Facilities				Harmon Peaking Factor M	Design Q (gpm)	Peak Design / Required Flow (MGD)	Trial Pipe Diameter (in)	A (ft^2)	Hydraulic Radius r_h	Slope (%)	V (ft/s)	provided (gpm)	provided (MGD)	Gravity (G), FM (F), Septic (S), Pressure (P)	Number of ET Beds	Number of Precast Tanks
Johnson Park	50	125	8.68	4.22	36.57	0.05	6	0.20	0.125	0.500	2.01	176.84	0.25	S	4	16
Park 4	1	2.5	0.17	4.46	0.77	0.00	6	0.20	0.125	0.500	2.01	176.84	0.25	S	1	1
Section Total	51	127.5	8.85		37.35	0.05								S	5	17
Marina 2	0.5	1.25	0.09	4.47	0.39	0.00	6	0.20	0.125	0.500	2.01	176.84	0.25	S	1	1
Lake Residential 10	202	505	35.05	3.97	139.21	0.20	6	0.20	0.125	0.500	2.01	176.84	0.25	S	13	52
Section Total	202.5	506.25	35.13		139.59	0.20								S	14	53
Runing Total	253.5	633.75	43.98		176.94	0.25									19	70
Commercial Recreation 2	16	40	2.78	4.33	12.03	0.02	6	0.20	0.125	0.500	2.01	176.84	0.25	S	1	4
Section Total	16	40	2.78		12.03	0.02								S	1	4
Running Total	269.5	673.75	46.76		188.97	0.27									20	74
Commercial Recreation 3	100	250	17.35	4.11	71.33	0.10	6	0.20	0.125	0.500	2.01	176.84	0.25	S	7	28
Sea Bee/Dyess Park	50	125	8.68	4.22	36.57	0.05	6	0.20	0.125	0.500	2.01	176.84	0.25	S	4	16
Section Total	150	375	26.03		107.90	0.16								S	11	44
Running Total	419.5	1048.75	72.78		296.87	0.43									31	118
Rural 1	1185	2962.5	205.60	3.45	708.70	1.02	10	0.55	0.208	0.520	2.88	705.38	1.02	S	75	300
Rural 2	9	22.5	1.56	4.37	6.83	0.01	6	0.20	0.125	0.500	2.01	176.84	0.25	S	1	2
Rural 3	682	1705	118.33	3.64	430.55	0.62	8	0.35	0.167	0.630	2.73	427.90	0.62	S	43	172
Rural 4	89	222.5	15.44	4.13	63.79	0.09	6	0.20	0.125	0.500	2.01	176.84	0.25	S	6	24
Rural 5	457	1142.5	79.29	3.76	298.28	0.43	6	0.20	0.125	1.500	3.48	306.29	0.44	S	29	116
Section Total	2422	6055	420.22		1508.15	2.17								S	154	614
West Side OSSF	2841.5	7103.75	493.00		1805.02	2.60									185	732
West Side Total	3503.5	8758.75			2257.5	3.25										

Assumptions:

		LUE
Dwelling Units per Acre		
	Residential Single Family	t
	Multi-Family	0.7
People per Living Unit Equivalent =		2.5
Avg Load per person (gpm)		0.0694
Gallons per person per day =		100
Dwelling Units per Septic Cluster =		t6
Prescast Tanks per Septic Cluster =		4

Harmon Peaking Factor:

$$M = 1 + \frac{14}{4 + \sqrt{P}}$$

P = Population in 1000

Manning's Equation:

$$V = \frac{1.49}{n}\left(r_h^{0.67}\right) S^{0.5}$$

n = 0.013

Notes:

1) All sewage will be sent to the Buck Creek Lift Station or the Hamby Waste Water Treatment Plant
2) All other proposed sewers not shown will be 6-inch lines at slopes of 0.5% or greater.
3) Pipe slopes will not exceed the maximum slope specified for the diameter in accordance with TNRCC Chapter 317 Requirements
4) All velocities exceed the minimum 2 fps criteria.
5) Infiltration and Inflow is not considered since it is new construction.
6) Harmon Peaking Factor is used to determine Peak Dry Design Flow

Calcualtion 6: West Side Sanitary Sewer
Scenario 2 (Partial Sewer - Low Pressure System)

Legend Location (North to South)	LUE	Population or Population Equivalent P	Avg Rate of Flow Q (gpm)	Harmon Peaking Factor M	Design Q (gpm)	Peak Design / Required Flow (MGD)	Trial Pipe Diameter (in)	A (ft^2)	V (ft/s)	Hydraulic Radius r_h	S_{hg}	provided (gpm)	provided (MGD)	Gravity (G), FM (F), Septic (S), Pressure (P)	Pressure Pipe Diameter (in)	Pressure Pipe Velocity (fps)
Central Sanitary Sewer Collection System																
Lake Residential 11	136	340	23.60	N/A	101.60	0.15	4	0.09	2.60	0.083	0.009	N/A	N/A	P	4	2.59
Lake Residential 12	282	705	48.93	N/A	189.20	0.27	4	0.09	4.84	0.083	0.029	N/A	N/A	P	4	4.83
Section Total	418	1045	72.52		290.80	0.42								P	6	3.30
Lake Residential 13	244	610	42.33	N/A	166.40	0.24	4	0.09	4.26	0.083	0.023	N/A	N/A	P	4	4.25
Section Total	662	1655	114.86		457.20	0.66								P	6	5.19
Total In Pressure System	**5665**	**14162.5**	**982.88**		**3859.00**	**5.56**								**P**	**15**	**7.01**

On-Site Sewer Facilities	LUE	Population or Population Equivalent P	Avg Rate of Flow Q (gpm)	Harmon Peaking Factor M	Design Q (gpm)	Peak Design / Required Flow (MGD)	Trial Pipe Diameter (in)	A (ft^2)	Slope (%)	Hydraulic Radius r_h	V (ft/s)	provided (gpm)	provided (MGD)	Gravity (G), FM (F), Septic (S), Pressure (P)	Number of Clusters	Number of Precast Tanks
Johnson Park	50	125	8.68	4.22	36.57	0.05	6	0.20	1.000	0.125	2.84	250.08	0.36	S	4	16
Park 4	1	2.5	0.17	4.46	0.77	0.00	6	0.20	1.000	0.125	2.84	250.08	0.36	S	1	1
Section Total	51	127.5	8.85		37.35	0.05								S	5	17
Marina 2	0.5	1.25	0.09	4.47	0.39	0.00	6	0.20	0.580	0.125	2.16	190.46	0.27	S	1	1
Lake Residential 10	202	505	35.05	3.97	139.21	0.20	6	0.20	0.500	0.125	2.01	176.84	0.25	S	13	52
Section Total	202.5	506.25	35.13		139.59	0.20								S	14	53
Runing Total	253.5	633.75	43.98		176.94	0.25								S	19	70
Commercial Recreation 2	16	40	2.78	4.33	12.03	0.02	6	0.20	0.500	0.125	2.01	176.84	0.25	S	1	4
Section Total	16	40	2.78		12.03	0.02								S	1	4
Running Total	269.5	673.75	46.76		188.97	0.27								S	20	74
Commercial Recreation 3	100	250	17.35	4.11	71.33	0.10	11	0.66	0.360	0.229	2.56	756.99	1.09	S	7	28
Sea Bee/Dyess Park	50	125	8.68	4.22	36.57	0.05	6	0.20	0.500	0.125	2.01	176.84	0.25	S	4	16
Section Total	150	375	26.03		107.90	0.16								S	11	44
Running Total	419.5	1048.75	72.78		296.87	0.43								S	31	118
Rural 1	1185	2962.5	205.60	3.45	708.70	1.02	6	0.20	0.500	0.125	2.01	176.84	0.25	S	75	300
Rural 2	9	22.5	1.56	4.37	6.83	0.01	6	0.20	0.500	0.125	2.01	176.84	0.25	S	1	2
Rural 3	682	1705	118.33	3.64	430.55	0.62	6	0.20	0.500	0.125	2.01	176.84	0.25	S	43	172
Rural 4	89	222.5	15.44	4.13	63.79	0.09	8	0.35	0.330	0.167	1.98	309.69	0.45	S	6	24
Rural 5	457	1142.5	79.29	3.76	298.28	0.43	6	0.20	0.500	0.125	2.01	176.84	0.25	S	29	116
Section Total	2422	6055	420.22		1508.15	2.17								S	154	614
West Side OSSF	2841.5	7103.75	493.00		1805.02	2.60								S	185	732
West Side Total	3503.5	8758.75			2262.22	3.26										

Assumptions:

		LUE
Dwelling Units per Acre		
	Residential Single Family	1
	Multi-Family	0.7
People per Living Unit Equivalent =		2.5
Avg Load per person (gpm)		0.0694
Gallons per person per day =		100
Dwelling Units per Septic Cluster =		16
Prescast Tanks per Septic Cluster =		4

EPA Formula:

Design Flow: Q=AN+B
Coeff A = 0.60
Factor B = 20
N = The number of LUE

Harmon Peaking Factor:

$$M = 1 + \frac{14}{4 + \sqrt{P}}$$

P = Population in 1000

Hazen -Williams Equation:

$$V = 1.318\, C \left(r_h^{0.63}\right) S_{hg}^{0.54}$$

C= 120
Est LUE per Cluster = 5

Manning's Equation:

$$V = \frac{1.49}{n}\left(r_h^{0.67}\right) S^{0.5}$$

n = 0.013

Notes:

1) All sewage will be sent to the Buck Creek Lift Station or the Hamby Waste Water Treatment Plant
2) All other proposed sewers not shown will be 6-inch lines at slopes of 0.5% or greater.
3) Pipe slopes will not exceed the maximum slope specified for the diameter in accordance with TNRCC Chapter 317 Requirements
4) All velocities exceed the minimum 2 fps criteria.
5) Infiltration and Inflow is not considered since it is new construction.
6) EPA fromulas obtained from the EPA's Alternative Wastewater Collection Systems Manual (EPA/625/1-91/024 dated October 1991)

East Side Gravity - Cost Calculations

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
1	6-Inch Gravity Sewer Line (All Depths)*	L.F.	250,150	$30.00	$7,504,500.00
2	8-Inch Gravity Sewer Line (All Depths)	L.F.	3,600	$45.00	$162,000.00
3	10-Inch Gravity Sewer Line (All Depths)	L.F.	7,500	$55.00	$412,500.00
4	4-Inch Water Class Rated Sewer Force Main	L.F.	8,500	$30.00	$255,000.00
5	6-Inch Water Class Rated Sewer Force Main	L.F.	3,000	$40.00	$120,000.00
6	8-Inch Water Class Rated Sewer Force Main	L.F.	3,250	$50.00	$162,500.00
7	12-Inch Water Class Rated Sewer Force Main	L.F.	14,000	$60.00	$840,000.00
8	Force Main Valves and Fittings	L.S.	1	$150,000.00	$150,000.00
9	Trench Safety System	L.F.	290,000	$2.00	$580,000.00
10	Standard 4-Foot Diameter Manhole	E.A.	523	$3,500.00	$1,828,750.00
11	Manhole Insert	EA.	523	$500.00	$261,250.00
12	Concrete Collar	EA.	523	$500.00	$261,250.00
13	Vacuum Testing of Manhole	EA.	523	$200.00	$104,500.00
14	4-Inch sewer service line (all depths)**	L.F.	125,075	$20.00	$2,501,500.00
15	Sewer Services	EA.	5,003	$500.00	$2,501,500.00
16	Storm Water Pollution Prevention Plan	LS.	1	$100,000.00	$100,000.00
17	Sewer Lift Station including all electrical, site work, piping, pumps, wetwell, valve vault, odor control, standby generator, security fencing, and buildings	EA.	7	$500,000.00	$3,500,000.00
				Total Material and Labor	$21,245,250.00
				Contingencies (20%)	$4,249,050.00
				Total	**$25,494,300.00**
				Per Living Unit Equivalent Cost	**$5,095.80**

* Estimated at 50 feet per LUE for internal collection
** Estimated at 25 feet per LUE

East Side Pressure - Cost Calculations - Individual Systems

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
1	Grinder Pump Packages	EA.	5,003	$4,500.00	$22,513,500.00
2	2-Inch Water Class Rated Sewer Pressure Pipe*	L.F.	5,000	$15.00	$75,000.00
3	4-Inch Water Class Rated Sewer Pressure Pipe**	L.F.	137,075	$20.00	$2,741,500.00
4	6-Inch Water Class Rated Sewer Pressure Pipe	L.F.	3,750	$30.00	$112,500.00
5	8-Inch Water Class Rated Sewer Pressure Pipe	L.F.	8,500	$40.00	$340,000.00
6	10-Inch Water Class Rated Sewer Pressure Pipe*	L.F.	5,000	$55.00	$275,000.00
7	12-Inch Water Class Rated Sewer Pressure Pipe	L.F.	5,500	$60.00	$330,000.00
8	15-Inch Water Class Rated Sewer Pressure Pipe	L.F.	8,000	$65.00	$520,000.00
9	Force Main Valves and Fittings	L.S.	1	$150,000.00	$150,000.00
10	Trench Safety System	L.F.	164,825	$2.00	$329,650.00
11	Sewer Services	EA.	5,003	$500.00	$2,501,500.00
12	Storm Water Pollution Prevention Plan	LS.	1	$100,000.00	$100,000.00
13	Sewer Lift Station including all electrical, site work, piping, pumps, wetwell, valve vault, odor control, standby generator, security fencing, and buildings	EA.	1	$500,000.00	$500,000.00
				Total Material and Labor	$30,488,650.00
				Contingencies (20%)	$6,097,730.00
				Total	**$36,586,380.00**
				Per Living Unit Equivalent Cost	**$7,312.89**

* Estimated amount
** Includes main line and additional service lines

East Side Pressure - Cost Calculations - Clustered Systems

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
1	Grinder Pump Packages (4 LUE Cluser)*	EA.	2,502	$6,000.00	$15,009,000.00
2	Septic Tank (3000 gallon Pre-Cast tanks, delivery and set fee, 1 load of sand)	EA.	2,502	$5,000.00	$12,507,500.00
3	4-Inch Water Class Rated Sewer Pressure Pipe*	L.F.	137,075	$20.00	$2,741,500.00
4	6-Inch Water Class Rated Sewer Pressure Pipe	L.F.	3,750	$30.00	$112,500.00
5	8-Inch Water Class Rated Sewer Pressure Pipe	L.F.	8,500	$40.00	$340,000.00
6	10-Inch Water Class Rated Sewer Pressure Pipe***	L.F.	5,000	$55.00	$275,000.00
7	12-Inch Water Class Rated Sewer Pressure Pipe	L.F.	5,500	$60.00	$330,000.00
8	15-Inch Water Class Rated Sewer Pressure Pipe	L.F.	8,000	$65.00	$520,000.00
9	Force Main Valves and Fittings	L.S.	1	$150,000.00	$150,000.00
10	Trench Safety System	L.F.	159,825	$2.00	$319,650.00
11	Sewer Services	EA.	0	$500.00	$0.00
12	Storm Water Pollution Prevention Plan	LS.	1	$100,000.00	$100,000.00
13	Sewer Lift Station including all electrical, site work, piping, pumps, wetwell, valve vault, odor control, standby generator, security fencing, and buildings	EA.	1	$500,000.00	$500,000.00
				Total Material and Labor	$32,905,150.00
				Contingencies (20%)	$6,581,030.00
				Total	**$39,486,180.00**
				Per Living Unit Equivalent Cost	**$7,892.50**

* Two grinder pumps for redundancy
** Includes main line and additional service lines

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
West Side - Cost Calculations (Individual Septic Systems)					
Septic Tank					
1	500 Gallon Pre-Cast Tank	EA.	2	$350.00	$700.00
2	Delivery and Set Fee for each tank	EA.	2	$100.00	$200.00
3	Required Sand - 1 Load	EA.	1	$100.00	$100.00
				Total Material Cost	$1,000.00
				Total Labor	$500.00
				Total Septic Tank Cost	**$1,500.00**
Evapotransiration Bed					
1	Bed Excavation and Class II Soil Backfill	LS.	1	$2,000.00	$2,000.00
2	Interceptor Pipe and Valve	LS.	1	$100.00	$100.00
3	Perforated Gravel-less Pipe	L.F.	668	$1.00	$668.00
4	Miscellaneous & Fittings	LS.	1	$100.00	$100.00
5	ET Bed Liner on Roll	EA.	6	$40.00	$240.00
				Total Material Cost	$3,108.00
				Total Labor (est. 50% of Material)	$1,554.00
				Total ET Bed Cost	**$4,662.00**
				Total Cost per LUE (Total Septic Tank + Total ET Bed Cost)	**$6,162.00**
				Contingencies (20%)	$1,232.40
				Total Cost per LUE W/ Contingencies (Total Septic Tank Cost + Total ET Bed Cost)	**$7,394.40**
				Total West Side Cost	**$25,906,280.40**

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
West Side - Cost Calculations (Clustered Septic Systems)					
1	4-Inch Service Lines to Collection System (16 LUE) (100 LF per LUE)	L.F.	1,600	$20.00	$32,000.00
2	8-Inch Diameter Pipe Collection System to Cluster Site	L.F.	740	$45.00	$33,300.00
3	4-Foot Diameter Sewer Manholes	EA.	4	$3,500.00	$14,000.00
4	Cluster Site Civil (Pavement, Meter, Misc.)	L.S.	1	$16,000.00	$16,000.00
5	Land For Cluster Site	L.S.	1	$5,000.00	$5,000.00
6	1,500 Gallon Pre-Cast Tank	EA.	4	$1,050.00	$4,200.00
7	Miscellaneous Risers, Piping, and Fittings	L.S.	1	$1,480.00	$1,480.00
8	Sand & Gravel	L.S.	1	$1,200.00	$1,200.00
9	Effluent Storage Tank and Pumps (3 days detention or 15,000 gallons)	L.S.	1	$25,000.00	$25,000.00
10	Effluent Force Main (Purple Pipe) to Cluster ET Beds	L.F.	740	$12.00	$8,880.00
11	ET Bed	S.F.	42,667	$1.87	$79,787.29
				Total Material and Labor	$220,847.29
				Contingencies (20%)	$44,169.46
				Total Cost for Cluster	**$265,016.75**
				Total Cost per LUE (16 LUE Cluster)	**$16,563.55**
				Total Clustered Septic Cost	**$58,030,386.04**

West Side Gravity - Cost Calculations

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
1	6-Inch Gravity Sewer Line (All Depths)*	L.F.	33,100	$30.00	$993,000.00
2	8-Inch Gravity Sewer Line (All Depths)	L.F.	9,500	$45.00	$427,500.00
3	6-Inch Water Class Rated Sewer Force Main	L.F.	13,250	$40.00	$530,000.00
4	Force Main Valves and Fittings	L.S.	1	$150,000.00	$150,000.00
5	Trench Safety System	L.F.	55,850	$2.00	$111,700.00
6	Standard 4-Foot Diameter Manhole	E.A.	85	$3,500.00	$298,200.00
7	Manhole Insert	EA.	85	$500.00	$42,600.00
8	Concrete Collar	EA.	85	$500.00	$42,600.00
9	Vacuum Testing of Manhole	EA.	85	$200.00	$17,040.00
10	4-Inch sewer service line (all depths)**	L.F.	16,550	$20.00	$331,000.00
11	Sewer Services	EA.	662	$500.00	$331,000.00
12	Storm Water Pollution Prevention Plan	LS.	1	$100,000.00	$100,000.00
13	Sewer Lift Station including all electrical, site work, piping, pumps, wetwell, valve vault, odor control, standby generator, security fencing, and buildings	EA.	1	$500,000.00	$500,000.00
				Total Material and Labor	$3,874,640.00
				Contingencies (20%)	$774,928.00
				Total	**$4,649,568.00**
				Per Living Unit Equivalent Cost	**$7,023.52**

* Estimated at 50 feet per LUE for internal collection
** Estimated at 25 feet per LUE

West Side - Cost Calculations (Individual Septic Systems)

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
	Septic Tank				
1	500 Gallon Pre-Cast Tank	EA.	2	$350.00	$700.00
2	Delivery and Set Fee for each tank	EA.	2	$100.00	$200.00
3	Required Sand - 1 Load	EA.	1	$100.00	$100.00
				Total Material Cost	$1,000.00
				Total Labor	$500.00
				Total Septic Tank Cost	**$1,500.00**
	Evapotransiration Bed				
1	Bed Excavation and Class II Soil Backfill	LS.	1	$2,000.00	$2,000.00
2	Interceptor Pipe and Valve	LS.	1	$100.00	$100.00
3	Perforated Gravel-less Pipe	L.F.	668	$1.00	$668.00
4	Miscellaneous & Fittings	LS.	1	$100.00	$100.00
5	ET Bed Liner on Roll	EA.	6	$40.00	$240.00
				Total Material Cost	$3,108.00
				Total Labor (est. 50% of Material)	$1,554.00
				Total ET Bed Cost	**$4,662.00**
				Total Cost per LUE (Total Septic Tank + Total ET Bed Cost)	**$6,162.00**
				Contingencies (20%)	$1,232.40
				Total Cost per LUE W/ Contingencies (Total Septic Tank Cost + Total ET Bed Cost)	**$7,394.40**
				Total West Side Cost	**$21,011,187.60**

West Side - Cost Calculations (Clustered Septic Systems)

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
1	4-Inch Service Lines to Collection System (16 LUE) (100 LF per LUE)	L.F.	1,600	$20.00	$32,000.00
2	8-Inch Diameter Pipe Collection System to Cluster Site	L.F.	740	$45.00	$33,300.00
3	4-Foot Diameter Sewer Manholes	EA.	4	$3,500.00	$14,000.00
4	Cluster Site Civil (Pavement, Meter, Misc.)	L.S.	1	$16,000.00	$16,000.00
5	Land For Cluster Site	L.S.	1	$5,000.00	$5,000.00
6	1,500 Gallon Pre-Cast Tank	EA.	4	$1,050.00	$4,200.00
7	Miscellaneous Risers, Piping, and Fittings	L.S.	1	$1,480.00	$1,480.00
8	Sand & Gravel	L.S.	1	$1,200.00	$1,200.00
9	Effluent Storage Tank and Pumps (3 days detention or 15,000 gallons)	L.S.	1	$25,000.00	$25,000.00
10	Effluent Force Main (Purple Pipe) to Cluster ET Beds	L.F.	740	$12.00	$8,880.00
11	ET Bed	S.F.	42,667	$1.87	$79,787.29
				Total Material and Labor	$220,847.29
				Contingencies (20%)	$44,169.46
				Total Cost for Cluster	**$265,016.75**
				Total Cost per LUE (16 LUE Cluster)	**$16,563.55**
				Total Clustered Septic Cost	**$47,065,318.09**

West Side Pressure - Cost Calculations - Individual Systems

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
1	Grinder Pump Packages	EA.	662	$4,500.00	$2,979,000.00
2	4-Inch Water Class Rated Sewer Pressure Pipe*	L.F.	22,550	$20.00	$451,000.00
3	6-Inch Water Class Rated Sewer Pressure Pipe	L.F.	19,000	$30.00	$570,000.00
4	Trench Safety System	L.F.	41,550	$2.00	$83,100.00
5	Sewer Services	EA.	662	$500.00	$331,000.00
6	Storm Water Pollution Prevention Plan	LS.	1	$100,000.00	$100,000.00
				Total Material and Labor	$4,514,100.00
				Contingencies (20%)	$902,820.00
				Total	**$5,416,920.00**
				Per Living Unit Equivalent Cost	**$8,182.66**

* Includes main line and additional service lines

West Side Pressure - Cost Calculations - Clustered Systems

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
1	Grinder Pump Packages (4 LUE Cluser)*	EA.	331	$6,000.00	$1,986,000.00
2	Septic Tank (3000 gallon Pre-Cast tanks, delivery and set fee, 1 load of sand)	L.F.	331	$5,000.00	$1,655,000.00
3	4-Inch Water Class Rated Sewer Pressure Pipe**	L.F.	22,550	$20.00	$451,000.00
4	6-Inch Water Class Rated Sewer Pressure Pipe	L.F.	19,000	$30.00	$570,000.00
5	Trench Safety System	L.F.	41,881	$2.00	$83,762.00
6	Sewer Services	EA.	662	$500.00	$331,000.00
7	Storm Water Pollution Prevention Plan	LS.	1	$100,000.00	$100,000.00
				Total Material and Labor	$5,176,762.00
				Contingencies (20%)	$1,035,352.40
				Total	**$6,212,114.40**
				Per Living Unit Equivalent Cost	**$9,383.86**

* Two grinder pumps for redundancy
** Includes main line and additional service lines

West Side - Cost Calculations (Individual Septic Systems)

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
	Septic Tank				
1	500 Gallon Pre-Cast Tank	EA.	2	$350.00	$700.00
2	Delivery and Set Fee for each tank	EA.	2	$100.00	$200.00
3	Required Sand - 1 Load	EA.	1	$100.00	$100.00
				Total Material Cost	$1,000.00
				Total Labor	$500.00
				Total Septic Tank Cost	**$1,500.00**
	Evapotransiration Bed				
1	Bed Excavation and Class II Soil Backfill	LS.	1	$2,000.00	$2,000.00
2	Interceptor Pipe and Valve	LS.	1	$100.00	$100.00
3	Perforated Gravel-less Pipe	L.F.	668	$1.00	$668.00
4	Miscellaneous & Fittings	LS.	1	$100.00	$100.00
5	ET Bed Liner on Roll	EA.	6	$40.00	$240.00
				Total Material Cost	$3,108.00
				Total Labor (est. 50% of Material)	$1,554.00
				Total ET Bed Cost	**$4,662.00**
				Total Cost per LUE (Total Septic Tank + Total ET Bed Cost)	**$6,162.00**
				Contingencies (20%)	$1,232.40
				Total Cost per LUE W/ Contingencies (Total Septic Tank Cost + Total ET Bed Cost)	**$7,394.40**
				Total West Side Cost	**$21,011,187.60**

West Side - Cost Calculations (Clustered Septic Systems)

Item No.	Item Description For Sanitary Sewer Collection System	Unit	APPROX. QUANTITY	Unit Cost	Total
1	4-Inch Service Lines to Collection System (16 LUE) (100 LF per LUE)	L.F.	1,600	$20.00	$32,000.00
2	8-Inch Diameter Pipe Collection System to Cluster Site	L.F.	740	$45.00	$33,300.00
3	4-Foot Diameter Sewer Manholes	EA.	4	$3,500.00	$14,000.00
4	Cluster Site Civil (Pavement, Meter, Misc.)	L.S.	1	$16,000.00	$16,000.00
5	Land For Cluster Site	L.S.	1	$5,000.00	$5,000.00
6	1,500 Gallon Pre-Cast Tank	EA.	4	$1,050.00	$4,200.00
7	Miscellaneous Risers, Piping, and Fittings	L.S.	1	$1,480.00	$1,480.00
8	Sand & Gravel	L.S.	1	$1,200.00	$1,200.00
9	Effluent Storage Tank and Pumps (3 days detention or 15,000 gallons)	L.S.	1	$25,000.00	$25,000.00
10	Effluent Force Main (Purple Pipe) to Cluster ET Beds	L.F.	740	$12.00	$8,880.00
11	ET Bed	S.F.	42,667	$1.87	$79,787.29
				Total Material and Labor	$220,847.29
				Contingencies (20%)	$44,169.46
				Total Cost for Cluster	**$265,016.75**
				Total Cost per LUE (16 LUE Cluster)	**$16,563.55**
				Total Clustered Septic Cost	**$47,065,318.09**

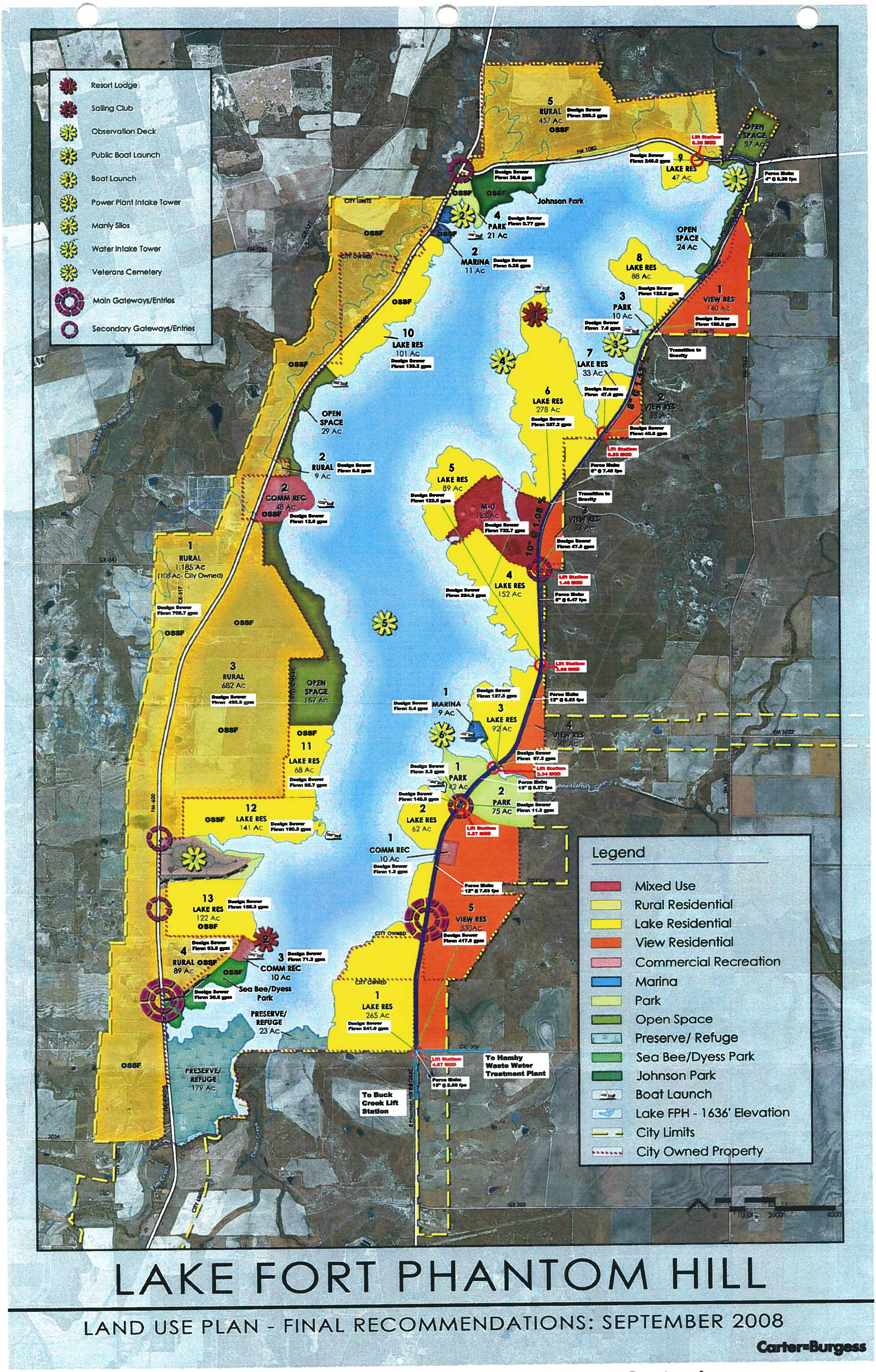
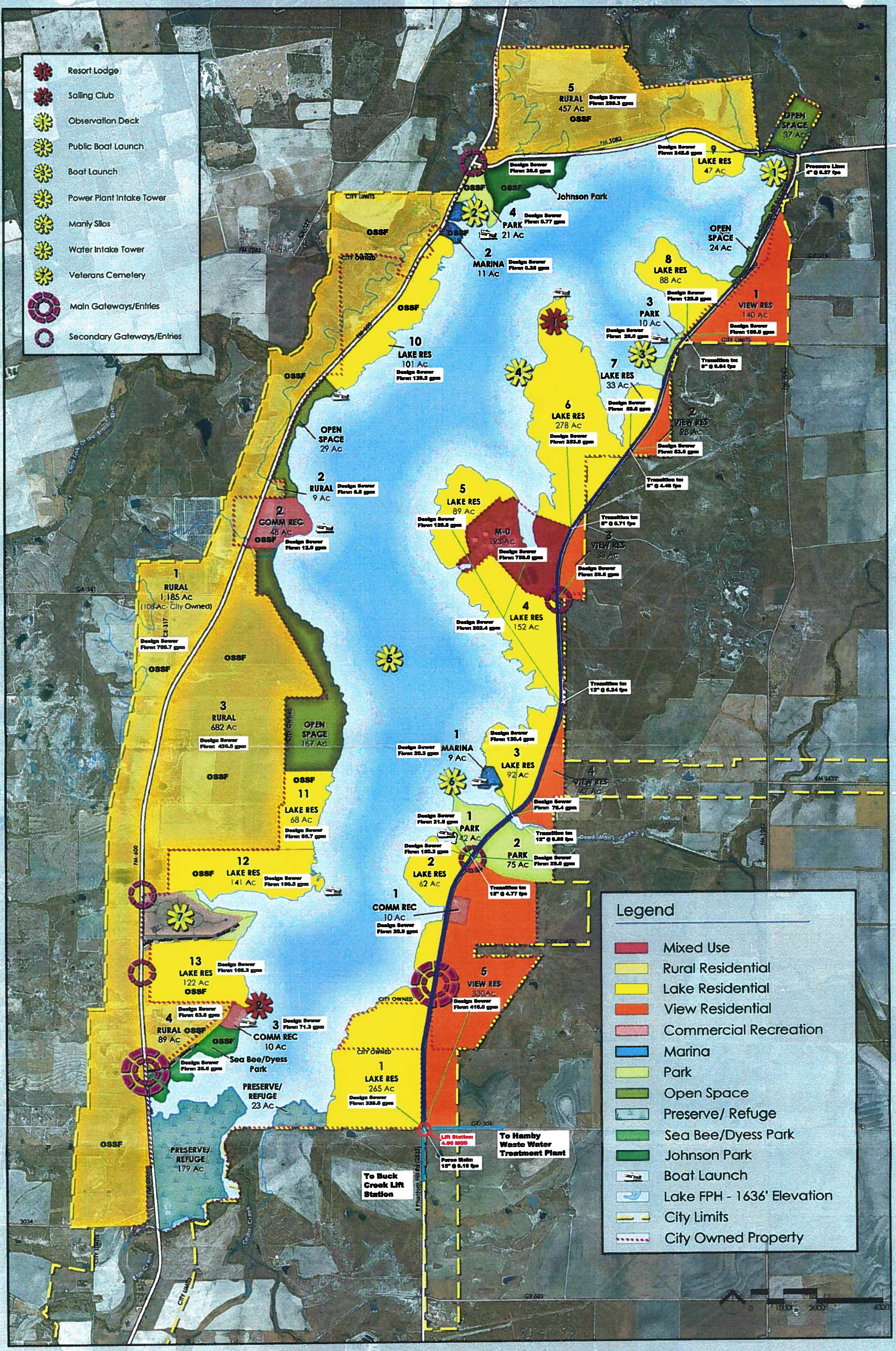


Exhibit 1A: Scenario 1A - East Side (Gravity System)



LAKE FORT PHANTOM HILL

LAND USE PLAN - FINAL RECOMMENDATIONS: SEPTEMBER 2008

Carter=Burgess

Exhibit 1B: Scenario 1B - East Side (Low Pressure System)

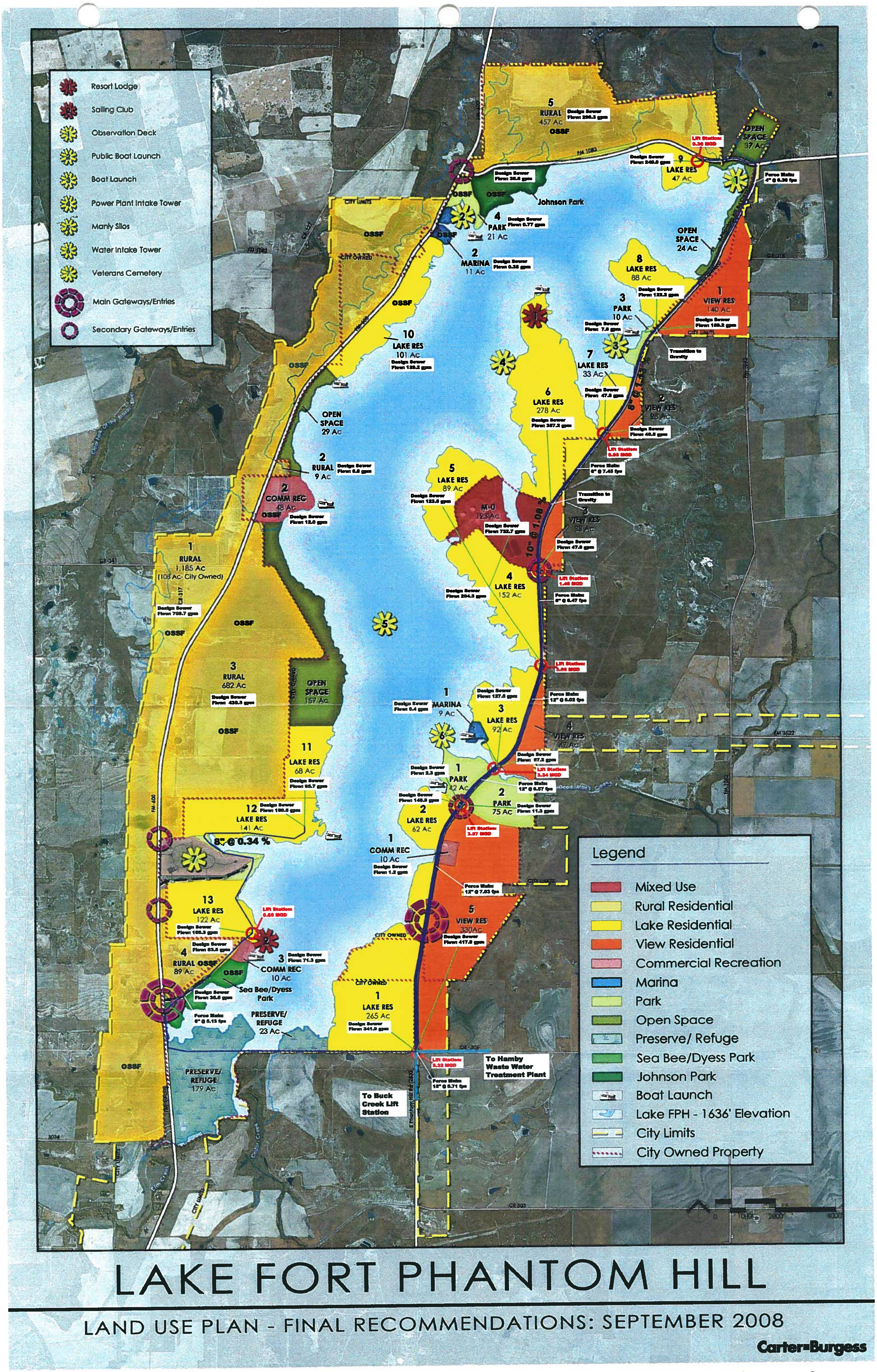
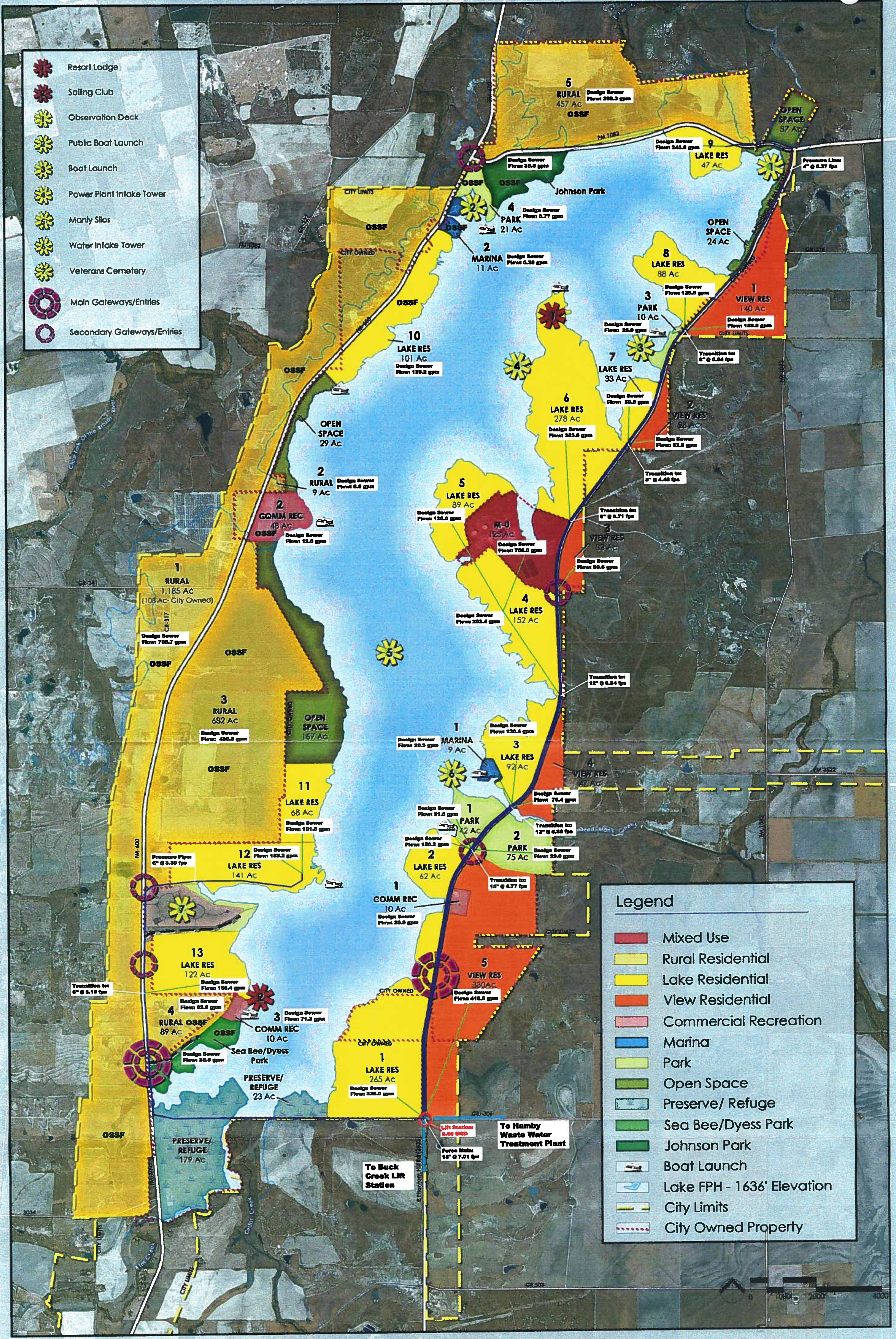


Exhibit 2A: Scenario 2A - East Side and Partial West Side (Gravity System)



LAKE FORT PHANTOM HILL

LAND USE PLAN - FINAL RECOMMENDATIONS: SEPTEMBER 2008

Carter=Burgess

Exhibit 2B: Scenario 2B - East Side and Partial West Side (Low Pressure System)

Lake Fort Phantom Hill Water System Modeling

March 2008

Prepared for:

CITY OF ABILENE

Prepared by:

JACOB & MARTIN, LTD.
CONSULTING ENGINEERS

STATE OF TEXAS
HENRY K. HARLE
98381
LICENSED
PROFESSIONAL ENGINEER
3/5/08

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 Purpose

The goals of this water modeling project are to evaluate the integrity of the existing water distribution system around Lake Fort Phantom Hill and to recommend water system improvements for full build-out and interim build-out periods established as part of the Lake Fort Phantom Hill Master Plan prepared by Jacobs, Carter & Burgess. The recommended improvements will serve as a basis for the design, construction, and financing of facilities required to meet Abilene's water demands around Lake Fort Phantom Hill resulting from the projected population growth and commercial development as forecasted in the Lake Fort Phantom Hill Master Plan.

1.2 Scope of Work

The major elements of the scope of this project include:

- Hydraulic evaluation and modeling of future water system around Lake Fort Phantom Hill.
- Development of water system improvement alternatives with cost estimates for full build-out and two interim build-out scenarios.

1.3 Abbreviations

Abbreviation	Definition
EST	Elevated Storage Tank
gpcd	Gallons per capita per day
gpm	Gallons per minute
GST	Ground Storage Tank
HGL	Hydraulic Grade Line
MG	Million Gallons
MGD	Million Gallons per Day
OPCC	Opinion of Probable Construction Cost
psi	Pounds per square inch
TCEQ	Texas Commission on Environmental Quality

2.0 POPULATION

Population projections are an important element in the analysis of water distribution systems. Water demands depend on the residential population and commercial development served by the distribution system. A thorough analysis of projected populations provides the basis for determining future water demands.

Population projections for the Lake Fort Phantom Hill service area were provided by Jacobs, Carter and Burgess. A summary of the population projections for the three build-out scenarios are shown in **Table 2.1**.

Population projections for the remainder of the water system were taken from the City of Abilene Water Distribution System Master Plan[1] as summarized in **Table 2.1**. The projected populations in the water distribution system master plan followed three planning periods, 2010, 2015 and 2030. For the purposes of this water modeling project it was assumed that the planning periods would coincide with the three scenarios, low end interim build-out, high end interim build-out and full build-out, included in the Lake Fort Phantom Hill Master Plan.

Table 2.1 Population Projections

Phase	Population		
	Water Distribution System Master Plan	**Lake Fort Phantom Hill Master Plan**	**Total**
2010 (Low End Interim)	124,607	940	125,547
2015 (High End Interim)	127,413	6,055	133,468
2030 (Full Build-out)	132,820	26,306	159,126

1 - City of Abilene Water Distribution Master Plan, Jacob & Martin, Ltd., *In Press*.

3.0 WATER DEMANDS

A water utility must be able to supply water at rates that fluctuate over a wide range. Yearly, monthly, daily, and hourly variations in water use occur, with higher use during dry years and in hot months. Also, water use typically follows a diurnal pattern, being low at night and peaking in the early morning and late afternoon. Rates most important to the hydraulic design and operation of pump stations and distribution system are average day, peak day, and peak hour. Peaking factors for peak day and peak hour demands for Abilene were developed as part of the City's Water Distribution System Evaluation, Modeling and Master Plan Project. An in depth discussion on the determination of the peaking factors is included in the Water Distribution System Master Plan Report.

Average day use is the total annual water use divided by the number of days in the year. The average day rate is used primarily as a basis for estimating maximum day and maximum hour demands. The average day rate is also used to estimate future revenues and operating costs.

Peak day use is the maximum quantity of water used on any one day of the year. The maximum day rate is used to size water supply hydraulics, treatment facilities, and pump stations. The raw water facilities must be adequate to supply water at the maximum day rate, and the treatment facilities must be capable of processing this quantity of water. A maximum day peaking factor of 2.0 was established for the Abilene water system as part of the City's Water Distribution System Master Plan.

Peak hour use is the peak rate at which water is required during any one hour of the year. Since minimum distribution pressures are usually experienced during peak hour demand conditions, the sizes and locations of distribution facilities are generally determined on the basis of this condition. Peak hour water requirements are partially met through the use of strategically located elevated storage. The use of elevated storage minimizes the required capacity of transmission mains and permits a more uniform and economical operation of the water supply, treatment, and pumping facilities. A peak hour peaking factor of 2.0 was established for the Abilene water system as part of the City's Water Distribution System Master Plan.

Water demand projections for the Lake Fort Phantom Hill service area were provided by Jacobs, Carter and Burgess. A summary of existing and projected water demands for the three build-out scenarios are shown in **Table 3.1**.

Table 3.1 Lake Fort Phantom Water Demand Projections

Phase	Water Demand (MGD)								
	Avg Day			Max Day			Peak Hour		
	Exit.	Proj.	Total	Exit.	Proj.	Total	Exit.	Proj.	Total
2010 (Low End Interim)	0.18	0.19	0.37	0.37	0.38	0.75	0.85	0.77	1.62
2015 (High End Interim)	0.22	1.05	1.27	0.45	2.11	2.56	1.00	4.22	5.22
2030 (Full Build-out)	0.52	4.04	4.56	1.25	8.09	9.34	2.70	16.17	18.87

Water demand projections for the remainder of the water system were taken from the City of Abilene Water Distribution System Master Plan as summarized in **Table 3.2**. As with the population projections, the projected water demands in the Water Distribution System Master Plan followed three planning periods, 2010, 2015 and 2030. Water demands for both the Lake Fort Phantom Hill Master Plan and Water Distribution System Master Plan are based on per capita water use summarized in **Table 3.3**. The City of Abilene per capita water use in **Table 3.3** was taken from the 2006 Region G Water Plan[2].

2 - http://www.brazoswater.org/229.htm

Table 3.2 City of Abilene Water Demand Projections

Year	Annual Water Demand (MG)			Avg. Day (MGD)	Peak Day (MGD)	Peak Hour (MGD)
	Abilene	Wholesale	Total			
2010	7,459	1,174	8,633	23.65	48.37	96.15
2015	7,534	1,245	8,779	24.05	49.24	96.97
2030	7,660	1,423	9,083	24.88	51.07	99.35

Table 3.3 2006 Region G Water Plan Projected Per Capita Water Use

Year	Abilene Per Capita Water Use (gpcd)
2010 (Low End Interim)	164
2015 (High End Interim)	162
2030 (Full Build-out)	158

4.0 WATER DISTRIBUTION SYSTEM ANALYSIS

Hydraulic analyses were conducted for the City of Abilene's water distribution system around Lake Fort Phantom Hill to establish required water system improvements to meet projected water demands through full build-out as forecasted in the Lake Fort Phantom Hill Master Plan. Various combinations of improvements and modifications were investigated to determine the most appropriate approach for meeting projected demands. Parameters used in developing the improvement program include increasing system reliability, simplifying system operations, meeting required fire flows, and maintaining residual pressures of at least 35 psi under peak hour demand conditions. The City's existing water system hydraulic model developed as part of the City's Water Distribution System Evaluation, Modeling and Master Plan Project was utilized to develop improvements around Lake Fort Phantom Hill. An in depth discussion on model development and calibration is included in the Water Distribution System Master Plan Report. This chapter discusses the results of the storage and pumping capacity evaluation and hydraulic analyses performed for the Lake Fort Phantom Hill service area. *Chapter 5.0 Water System Improvements* includes a detailed discussion of proposed improvements developed as part of the hydraulic analyses presented in this chapter

4.1 TCEQ Storage and Pumping Capacity Evaluation

A. Elevated and Total Storage

The City is required to meet the TCEQ elevated storage capacity requirement of 100 gallons per connection and total storage capacity requirement of 200 gallons per connection. The proposed Lake Fort Phantom Hill elevated and total storage in comparison to TCEQ requirements are shown in **Table 4.1**.

B. Pumping

The City of Abilene is required to meet the TCEQ service pump capacity requirements established in 30 TAC §290.45(b)(2)(F) and summarized in **Table 4.2. Table 4.3** summarizes the proposed pumping capacity for the City of

Abilene Lake Fort Phantom Hill service area in comparison to TCEQ requirements.

Table 4.1 TCEQ Elevated Storage Requirements

Phase	Connections	Total Storage (MG)		Elevated Storage (MG)	
		Proposed	Required	Proposed	Required
Low End Interim[1]	786	10.00	0.16	0.00	0.08
High End Interim	2,832	10.50	0.57	0.50	0.28
Full Build-out	10,933	11.50	0.72	1.50	1.09

(1) Elevated storage for Low End Interim Build-out scenario will be provided by existing elevated storage in the water system.

Table 4.2 TCEQ Service Pumping Capacity Criteria

Elevated Storage Capacity	Service Pumping Capacity Requirement[1]
≥ 200 gallons per connection	Two service pumps with a minimum combined capacity of 0.6 gpm per connection at each pressure plane
< 200 gallons per connection	The lesser of (a) or (b):
	(a) Total pumping capacity of 2.0 gpm per connection per pressure plane
	(b) Total pumping capacity of at least 1,000 gpm and the ability to meet peak hourly demands with the largest pump out of service

(1) According to 30 TAC §290.45(b)(2)(F)

Table 4.3 TCEQ Pumping Capacity Requirements

Phase	Connections	Elevated Storage (MG)	Gallons per connection	Pump Capacity (MGD)	
				Proposed	Required
Low End Interim[1]	786	0.00	0	0.00	2.26
High End Interim	2,832	0.50	177	10.00	8.16
Full Build-out[2]	10,933	1.50	137	20.00	31.49

(1) Pumping capacity for Low End Interim Build-out scenario will be provided by existing pump capacity in the water system.
(2) Proposed pumping capacity for Full Build-out scenario is able to meet peak hourly demands in combination with elevated storage; therefore, 2.0 gpm per connection does not govern pump capacity requirement.

4.2 Storage and Pumping Evaluation

The following sections summarize an evaluation of the storage and pumping capacity for the Lake Fort Phantom Hill development area based on criteria typically more stringent than the TCEQ requirements. These criteria take into consideration many additional factors including operational flexibility, fire protection, and energy efficiency.

A. Elevated Storage Evaluation

The design criteria used to analyze existing elevated storage tank capacity is the ability to provide adequate storage for peak hour demands plus emergency storage for fire protection. It is typically assumed that half of the elevated storage tank capacity is used to meet peak hourly demands in excess of the maximum day rate (equalization volume), while the other half of the tank is used for fire protection and emergency conditions (fire/emergency volume).

According to the Insurance Services Offices (ISO), the maximum fire flow a municipality is required to provide is 3,500 gpm for 3-hour duration. While typical residential and commercial fire flow requirements are 1,000 gpm and 1,500 gpm, respectively, some industrial fire flows can approach the 3,000 to 3,500 gpm range or greater. Due to the fact that the proposed development around Lake Fort Phantom Hill is comprised primarily of residential and commercial development, a fire flow requirement of 1,500 gpm for 3-hour duration was selected for this evaluation.

Table 4.4 provides a summary of the elevated storage requirements using two criteria. Criteria 1 represents twice the required equalization volume while Criteria 2 represents the equalization volume plus the fire/emergency volume. The required total elevated storage volume was based on the greater of the two criteria. Elevated storage is not proposed in the Low End Interim Build-out phase. Elevated storage for this phase would be provided by existing elevated storage in the water system.

Table 4.4 Elevated Storage Capacity Evaluation

Phase	Max Day Demand (MGD)	Peak Hour Demand (MGD)	Peak Demand[1] (MGD)	50% of Peak Demand (MGD)	Req'd Equalization Vol[2] (MG)	Req'd Fire Vol[3] (MG)	Elevated Storage (MG)		
							Req'd Total Vol[4]		Prop
							Criteria 1	Criteria 2	
Low End Interim[5]	0.75	1.62	0.86	0.43	0.07	0.18	0.14	0.25	0.00
High End Interim	2.56	5.22	2.67	1.33	0.22	0.27	0.44	0.49	0.50
Full Build-out	9.34	18.87	9.53	4.77	0.79	0.27	1.59	1.06	1.50

(1) The difference between the maximum day and peak hour demands
(2) The volume required to meet 50% of the peak demand for a duration of 4 hours
(3) The volume required to meet a 1,500 gpm fire flow for 3 hours
(4) Criteria 1 is twice the required equalization volume and Criteria 2 is the required equalization volume plus the required fire flow
(5) Elevated storage for Low End Interim Build-out scenario will be provided by existing elevated storage in the water system.

B. Pumping Evaluation

The design criteria recommended for pump station capacity is providing a firm pumping capacity to meet 50% of the peak hour demand. The firm pumping capacity is defined as the total available pumping capacity with the largest pump out of service. Shown in **Table 4.5** is the recommended total and firm pumping capacity for the Lake Fort Phantom Hill area.

Table 4.5 Pumping Capacity Evaluation

Pressure Plane	Pump Capacity (MGD)		
	Proposed		Required Firm[1]
	Total	Firm	
Low End Interim[2]	0.00	0.00	0.81
High End Interim	10.00	4.00	2.61
Full Build-out	20.00	14.00	9.44

(1) 50% of the Peak Hour Demand
(2) Pumping capacity for Low End Interim Build-out scenario will be provided by existing pump capacity in the water system.

4.3 Hydraulic Model Analysis

Hydraulic analyses were performed for the Lake Fort Phantom Hill area for four operating conditions: average day, maximum day, peak hour, and maximum day with fire flow. The various operating conditions were modeled for each build-out scenario.

Average day demand is defined as the total water used in a year divided by the number of days in the year. Average day model runs are used to evaluate the ability of the distribution system to fill elevated storage under lower demand conditions after a peak hour event. During average day demand periods, the pumps will typically meet system demand and also be used to fill the elevated and ground storage tanks. The elevated and ground storage tanks were assumed to be about 75% full for the average day model run.

Peak day demand is defined as the usage on the single day of the year with the highest demand. Peak day model runs assess the ability of the system to meet demands with adequate residual pressures and maintain levels in elevated storage facilities. In a peak day model run, the pumps will meet the demand of the system, and the elevated and ground storage tank levels should see little change. In this condition, the elevated and ground storage tanks were assumed to be approximately 95% full, providing a maximum system HGL against which the pumps would operate.

Peak hour demand represents the single hour of the year with the highest system demand. Peak hour model runs are used to assess the ability of the distribution system to maintain residual pressures of at least 35 psi at all locations. The analysis is also used to examine whether elevated storage drain rates are excessive. According to general industry practices, pump stations are typically sized to meet the peak day demand of the system, and the elevated storage facilities should meet the difference in demand between maximum day and peak hour. For the peak hour model run, the elevated and ground storage tanks were assumed to be 50% full to represent a worst case pressure scenario.

For fire flow analyses the model was run with a fire flow demand of 1,000 gpm superimposed on maximum day demands to determine fire suppression capabilities.

The TCEQ required minimum pressure within a distribution system is 35 psi under peak hour demand conditions. Residual pressures throughout the system are required to be 20 psi and higher under fire flow conditions (1,000 gpm for the model runs in this study). Headloss and velocity in the pipelines are additional criteria used to analyze the water system. Typically, headlosses in water lines should not exceed 4 feet/1,000 feet, and velocities should not exceed 7 feet/second. Headloss and velocity criteria for this analysis were established at 2 feet/1,000 feet and 5 feet/second, respectively.

A. Water Demands

The demands for average day conditions were provided by Jacobs, Carter and Burgess. Peak day and peak hour demands were calculated using the peaking factors established for the City of Abilene water system as part of the City's Water Distribution System Master Plan. The demands for each condition were distributed around Lake Fort Phantom Hill as point demands. The point demands were distributed based on landuse type and phasing. The landuse types included rural residential, low density residential, medium density residential, commercial/recreational, industrial, and parks. A summary of the point demands for Lake Fort Phantom Hill are shown on **Figure 5.1**. The projected water demands are arranged by landuse type. The total demand in the model for the Lake Fort Phantom Hill service area is a combination of the existing demands and projected point demands provided by Jacobs, Carter and Burgess as shown in **Table 3.1**.

B. Low End Interim Build-out

The projected average day demand for the Lake Fort Phantom Hill area is approximately 0.37 MGD. Model pressures generally ranged from 70 to 115 psi. The pipeline headlosses typically ranged from 0 to 3 feet/1,000 feet, and velocities generally ranged from 0 to 2 feet/second.

The peak day demand was projected to be approximately 0.75 MGD. Model pressures typically ranged from 70 to 115 psi. The highest and lowest pressures occurred in the same areas as the average day demand model run. Velocities typically ranged from 0 to 2 feet/second, and pipe headlosses were generally between 0 and 2 ft/1,000 feet.

The peak hour demand was projected to be approximately 1.62 MGD. Model pressures generally ranged from 50 to 100 psi. Model velocities typically ranged from 0 to 4 feet/second, and pipe headlosses were generally between 0 and 7 feet/1,000 feet. There were a few pipes with headlosses in excess of 2 feet/1,000 feet; however, they exhibited negligible overall headloss. The peak hour model analysis indicated that with the proposed improvements through the Low End Interim Build-out period the distribution system is capable of maintaining residual pressures of at least 35 psi throughout the Lake Fort Phantom Hill area during peak hour demand conditions.

The fire flow analysis indicated that all areas around Lake Fort Phantom Hill are capable of providing fire flows of 500 gpm while maintaining a residual pressure of 20 psi. The system is capable of providing fire flows of 1,000 gpm on the west side of the lake up to Seebee Park Road and east side of the lake up to Cove Road.

C. High End Interim Build-out

The projected average day demand for the Lake Fort Phantom Hill area is approximately 1.27 MGD. Model pressures generally ranged from 40 to 85 psi. The pipeline headlosses typically ranged from 0 to 2 feet/1,000 feet, and velocities generally ranged from 0 to 4.5 feet/second. The analysis indicates that the distribution system improvements through the High End Interim Build-out period have the capability to adequately fill the proposed elevated storage at rates comparable to the drain rates experienced under a peak hour condition.

The peak day demand was projected to be approximately 2.56 MGD. Model pressures typically ranged from 40 to 80 psi. The highest and lowest pressures occurred in the same areas as the average day demand model run. Velocities typically ranged from 0 to 4 feet/second, and pipe headlosses were generally between 0 and 2 ft/1,000 feet. The analysis indicated that the distribution system improvements through the High End Interim Build-out period have the capability to maintain the level in the proposed elevated storage tank under peak day demand conditions.

The peak hour demand was projected to be approximately 5.22 MGD. Model pressures generally ranged from 40 to 70 psi. Model velocities typically ranged from 0 to 4 feet/second, and pipe headlosses were generally between 0 and 7 feet/1,000 feet. There were a few pipes with headlosses in excess of 2 feet/1,000 feet; however, those pipes exhibited negligible overall headloss. The peak hour model analysis indicated that with the proposed water system improvements through the High End Interim Build-out period the distribution system is capable of maintaining residual pressures of at least 35 psi in the Lake Fort Phantom Hill area during peak hour demand conditions.

The fire flow analysis indicated that all areas around Lake Fort Phantom Hill are capable of providing fire flows of 500 gpm while maintaining a residual pressure of 20 psi. The system is capable of providing fire flows of 1,000 gpm on the west side of the lake up to Apache Lane and on the east side of the lake up to Dixon Road.

D. Full Build-out

The projected average day demand for the Lake Fort Phantom Hill area is approximately 4.56 MGD. Model pressures generally ranged from 40 to 80 psi. The pipeline headlosses typically ranged from 0 to 2 feet/1,000 feet, and velocities generally ranged from 0 to 4.5 feet/second. The analysis indicates that the distribution system improvements through the Full Build-out period have the capability to adequately fill proposed elevated storage at rates comparable to the drain rates experienced under a peak hour condition.

The peak day demand was projected to be approximately 9.34 MGD. Model pressures typically ranged from 45 to 85 psi. The highest and lowest pressures occurred in the same areas as the average day demand model run. Velocities typically ranged from 0 to 4 feet/second, and pipe headlosses were generally between 0 and 7 ft/1,000 feet. The analysis indicated that the distribution system improvements through the Full Build-out period have the capability to maintain the level in proposed elevated storage tanks under peak day demand conditions.

The peak hour demand was projected to be approximately 18.87 MGD. Model pressures generally ranged from 45 to 85 psi. Model velocities typically ranged from 0 to 4 feet/second, and pipe headlosses were generally between 0 and 7 feet/1,000 feet. There were a few pipes with headlosses in excess of 2 feet/1,000 feet; however, they exhibited negligible overall headloss. The peak hour model analysis indicated that with the proposed improvements through the Full Build-out period the distribution system is capable of maintaining residual pressures of at least 35 psi in the Lake Fort Phantom Hill area during peak hour demand conditions.

The fire flow analysis indicated that all areas around Lake Fort Phantom Hill are capable of providing fire flows of 1,000 gpm while maintaining a residual pressure of 20 psi.

5.0 WATER SYSTEM IMPROVEMENTS

Water system improvements were developed for the Lake Fort Phantom Hill area to maintain high quality water service and provide for the projected residential and commercial development. The water system improvements were separated to satisfy three build-out scenarios: Low End Interim Build-out, High End Interim Build-out, and Full Build-out. The recommended improvements will provide the required capacity and reliability to meet projected water demands through the Full Build-out scenario. All of the proposed capital improvements for the water system are shown in **Figure 5.1**. Locations shown for new mains and other recommended improvements were generalized for hydraulic analyses. Specific alignments and sites will have to be determined as part of the design process. Unit costs used to estimate project costs of the water system improvements are shown in **Table 5.1**, and **Table 5.2** provides and a summary of the opinion of probable construction cost for the proposed improvements. The proposed improvements are separated into the three planning scenarios.

Unit costs are based on a review of bid tabs for several projects ranging in size. These costs are in terms of 2008 dollars and include an allowance for engineering, surveying, geotechnical and contingencies. The project costs do not include right-of-way acquisition. It is understood that development around Lake Fort Phantom Hill may make it necessary to construct some future improvements sooner than anticipated.

Table 5.1 Estimated Unit Cost for Water System Construction

Item Description	Unit	Unit Cost
24" WL & Appurtenances	LF	$120 / LF
20" WL & Appurtenances	LF	$100 / LF
16" WL & Appurtenances	LF	$88 / LF
12" WL & Appurtenances	LF	$66 / LF
36" Boring and Casing	LF	$380 / LF
30" Boring and Casing	LF	$330 / LF
24" Boring and Casing	LF	$260 / LF
20" Boring and Casing	LF	$220 / LF
Pavement Repair	LF	$35 / LF
1.0 MG Elevated Tank	LS	$1,800,000
0.5 MG Elevated Tank	LS	$1,300,000
Pump Station – New 10 MGD	LS	$2,000,000
Pump Station Expansion – 10 MGD	LS	$1,000,000
WTP Expansion - 8 MGD	LS	$12,000,000

Figure 5.1 Lake Fort Phantom Hill Water System Improvements

Table 5.1
Water System Improvements
Opinions Of Probable Project Cost

Phase	Phase Description	Construction Items	Quantity	Units	Unit Price	Costs
1	**Low Interim Build-out**	20" WL & Appurtenances	11,000	LF	$100	$1,100,000
		16" WL & Appurtenances	8,500	LF	$88	$748,000
		12" WL & Appurtenances	19,000	LF	$66	$1,254,000
		36" Boring and Casing	100	LF	$380	$38,000
		24" Boring and Casing	100	LF	$260	$26,000
		20" Boring and Casing	300	LF	$220	$66,000
		Pavement Repair	200	LF	$35	$7,000
		Cedar Creek Crossing	1	LS	$100,000	$100,000
		Elm Creek Crossing	1	LS	$100,000	$100,000
					Subtotal	$3,439,000
					Contingency @ 20%	$687,800
					Total Construction Cost	$4,126,800
					Engineering, Surveying & Geotech @ 15%	$619,020
					Total Project Cost	$4,745,820
2	**High Interim Build-out**	24" WL & Appurtenances	3,000	LF	$120	$360,000
		20" WL & Appurtenances	32,000	LF	$100	$3,200,000
		16" WL & Appurtenances	33,000	LF	$88	$2,904,000
		30" Boring and Casing	400	LF	$330	$132,000
		24" Boring and Casing	400	LF	$260	$104,000
		Pavement Repair	400	LF	$35	$14,000
		Elm Creek Crossing	1	LS	$100,000	$100,000
		Miscellaneous Creek Crossings	1	LS	$100,000	$100,000
		500,000 Gal Elevated Tank	1	LS	$1,300,000	$1,300,000
		Pump Station - New 10 MGD	1	LS	$2,000,000	$2,000,000
					Subtotal	$10,214,000
					Contingency @ 20%	$2,042,800
					Total Construction Cost	$12,256,800
					Engineering, Surveying & Geotech @ 15%	$1,838,520
					Total Project Cost	$14,095,320
3	**Full Build-out**	20" WL & Appurtenances	36,000	LF	$100	$3,600,000
		16" WL & Appurtenances	31,000	LF	$88	$2,728,000
		12" WL & Appurtenances	3,000	LF	$66	$198,000
		30" Boring and Casing	300	LF	$330	$99,000
		24" Boring and Casing	200	LF	$260	$52,000
		20" Boring and Casing	200	LF	$220	$44,000
		Pavement Repair	500	LF	$35	$17,500
		Cedar Creek Crossing	1	LS	$100,000	$100,000
		Elm Creek Crossing	1	LS	$100,000	$100,000
		Miscellaneous Creek Crossings	1	LS	$100,000	$100,000
		1.0 MG Elevated Tank	1	LS	$1,800,000	$1,800,000
		Pump Station - Expans 10 MGD	1	LS	$1,000,000	$1,000,000
		NEWTP Expansion - 8 MGD	1	LS	$12,000,000	$12,000,000
					Subtotal	$21,838,500
					Contingency @ 20%	$4,367,700
					Total Construction Cost	$26,206,200
					Engineering, Surveying & Geotech @ 15%	$3,930,930
					Total Project Cost	$30,137,130
	CITY OF ABILENE - LAKE FORT PHANTOM HILL TOTAL WATER SYSTEM IMPROVEMENTS COSTS					$48,978,270

5.1 Water System Improvements

A. Low End Interim Build-out

The projected development around Lake Fort Phantom Hill associated with the Low End Interim Build-out has little impact on the existing water distribution system around the lake. Therefore, the proposed improvements through Low End Interim Build-out are primarily aimed at addressing existing deficiencies in the water distribution system around Lake Fort Phantom as identified in the City's Water Distribution System Master Plan. The deficiencies identified in the Water Distribution System Master Plan include inadequate fire flows (less than 500 gpm) around the lake and low pressures (below 35 psi) during peak hour demand conditions. The 12" water line loop around the north side of the lake and 16" water line loop along Neas Road address these two existing deficiencies. The proposed 20" water line along East Lake Road provides water line capacity for projected residential development along the east side of the lake. The proposed improvements associated with the Low End Interim Build-out Phase are shown on **Figure 5.1**.

B. High End Interim Build-out

Proposed water system improvements through the High End Interim Build-out phase include a dedicated high service pump station for the Lake Fort Phantom Hill service area located at the NEWTP, proposed 0.5 MG EST located on the east side of the lake, 20" water lines on the east side of the lake to serve projected residential and commercial growth and fill proposed elevated storage, and 16" and 24" water lines to the west side of the lake to serve projected residential growth.

By constructing a dedicated high service pump station for the Lake Fort Phantom Hill service area the HGL for the Lake Fort Phantom Hill Service area can be reduced by approximately 60 feet. The creation of a separate pressure plane for the Lake Fort Phantom Hill service area also allows for more efficient operation of the proposed elevated storage tanks. The proposed pump station shall have a total pumping capacity of 10 MGD and firm pumping capacity of 4 MGD.

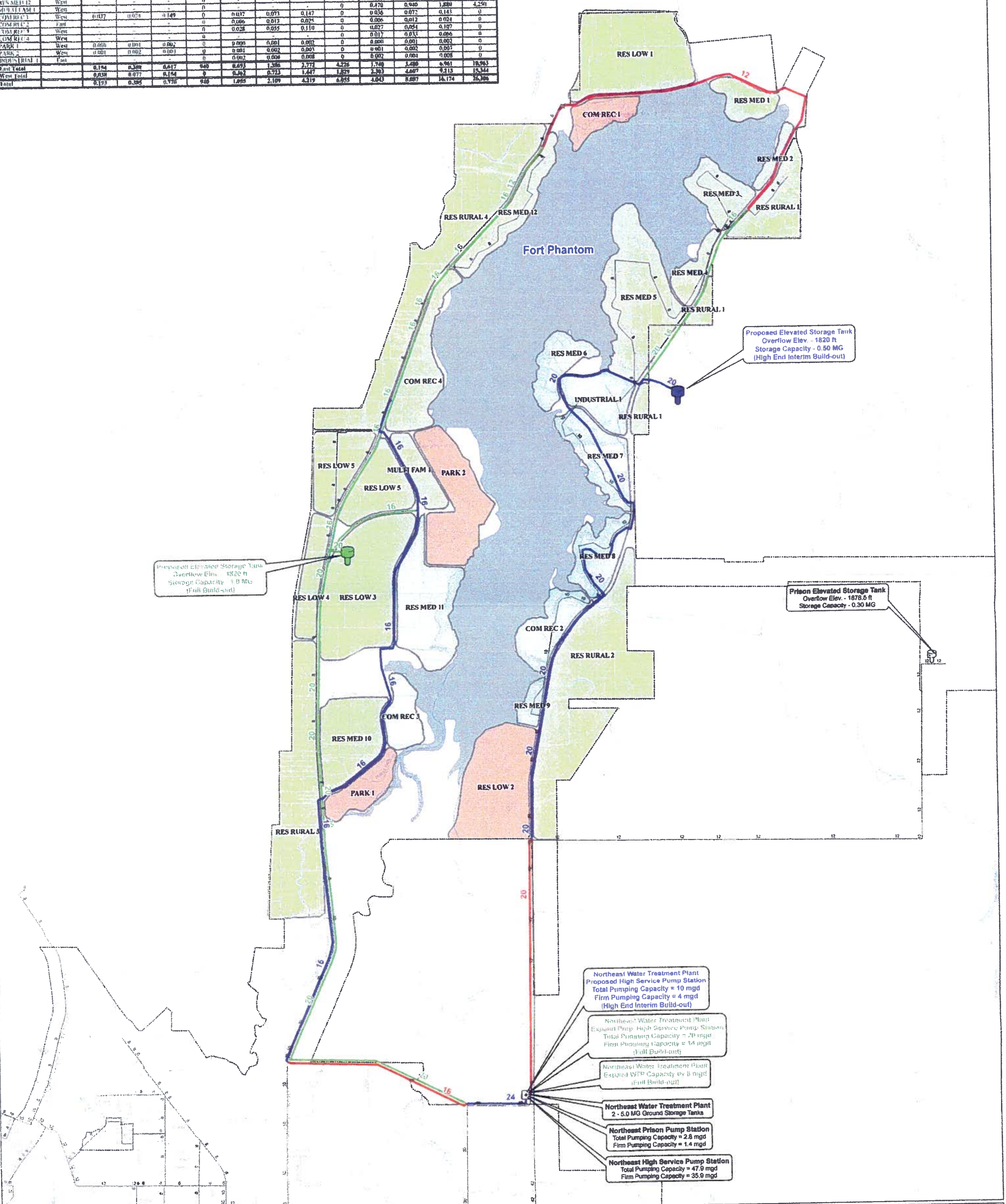
The proposed 0.5 MG EST is necessary to meet elevated storage requirements outlined in this report. The proposed improvements associated with the High End Interim Build-out Phase are shown on **Figure 5.1**.

C. Full Build-out

Proposed water system improvements through the Full Build-out phase include expansion of the dedicated high service pump station for the Lake Fort Phantom Hill service area, proposed 1.0 MG EST located on the west side of the lake, expansion of the NEWTP, 16" and 20" water lines on the east side of the lake to serve projected residential and commercial growth, and 12", 16" and 20" water lines on the west side of the lake to serve projected residential and commercial growth and fill proposed elevated storage.

Expansion of the dedicated high service pump station and expansion of the treatment capacity at NEWTP are required to meet maximum day and peak hour demands resulting from projected residential and commercial growth through the Full Build-out Phase. The proposed 1.0 MG EST is necessary to meet elevated storage requirements outlined in this report. The proposed improvements associated with the Full Build-out Phase are shown on **Figure 5.1**.

Landuse	Side of Lake (East / West)	Low Interim Build-out Avg Day Demand (MGD)	Low Interim Build-out Max Day Demand (MGD)	Low Interim Build-out Peak Hour Demand (MGD)	Low Interim Build-out Pop.	High Interim Build-out Avg Day Demand (MGD)	High Interim Build-out Max Day Demand (MGD)	High Interim Build-out Peak Hour Demand (MGD)	High Interim Build-out Pop.	Full Build-out Avg Day Demand (MGD)	Full Build-out Max Day Demand (MGD)	Full Build-out Peak Hour Demand (MGD)	Full Build-out Pop.
RES RURAL 1	East	-	-	-	0	-	-	-	0	0.037	0.075	0.149	236
RES RURAL 2	East	-	-	-	0	-	-	-	0	0.120	0.240	0.480	760
RES RURAL 3	West	-	-	-	0	-	-	-	0	0.079	0.158	0.315	499
RES RURAL 4	West	-	-	-	0	-	-	-	0	0.109	0.217	0.435	688
RES LOW 1	West	-	-	-	0	-	-	-	0	0.266	0.532	1.065	1,685
RES LOW 2	East	0.154	0.308	0.617	940	0.232	0.465	0.930	1,435	0.227	0.453	0.907	1,435
RES LOW 3	West	-	-	-	0	-	-	-	0	0.281	0.562	1.125	1,780
RES LOW 4	West	-	-	-	0	-	-	-	0	0.084	0.167	0.335	530
RES LOW 5	West	-	-	-	0	-	-	-	0	0.224	0.447	0.894	1,415
RES MED 1	East	-	-	-	0	-	-	-	0	0.098	0.196	0.393	621
RES MED 2	East	-	-	-	0	-	-	-	0	0.037	0.075	0.149	236
RES MED 3	East	-	-	-	0	-	-	-	0	0.140	0.279	0.559	884
RES MED 4	East	-	-	-	0	-	-	-	0	0.079	0.158	0.315	499
RES MED 5	East	-	-	-	0	-	-	-	0	0.452	0.904	1.808	2,861
RES MED 6	East	-	-	-	0	0.028	0.057	0.113	175	0.129	0.257	0.514	814
RES MED 7	East	-	-	-	0	0.214	0.428	0.856	1,321	0.209	0.418	0.835	1,321
RES MED 8	East	-	-	-	0	0.164	0.329	0.658	1,015	0.160	0.321	0.641	1,015
RES MED 9	East	-	-	-	0	0.045	0.091	0.181	280	0.044	0.088	0.177	280
RES MED 10	West	-	-	-	0	-	-	-	0	0.247	0.495	0.990	1,566
RES MED 11	West	-	-	-	0	0.296	0.593	1.185	1,829	0.289	0.578	1.156	1,829
RES MED 12	West	-	-	-	0	-	-	-	0	0.174	0.348	0.697	1,103
MULTI FAM 1	West	-	-	-	0	-	-	-	0	0.470	0.940	1.880	4,250
COM REC 1	West	0.037	0.074	0.149	0	0.037	0.073	0.147	0	0.036	0.072	0.143	0
COM REC 2	East	-	-	-	0	0.006	0.013	0.025	0	0.006	0.012	0.024	0
COM REC 3	West	-	-	-	0	0.028	0.055	0.110	0	0.027	0.054	0.107	0
COM REC 4	West	-	-	-	0	-	-	-	0	0.017	0.033	0.066	0
PARK 1	West	0.000	0.001	0.002	0	0.000	0.001	0.002	0	0.000	0.001	0.002	0
PARK 2	West	0.001	0.002	0.003	0	0.001	0.002	0.003	0	0.001	0.002	0.003	0
INDUSTRIAL 1	East	-	-	-	0	0.002	0.004	0.008	0	0.002	0.004	0.008	0
East Total		0.154	0.308	0.617	940	0.693	1.386	2.772	4,226	1.740	3.480	6.961	10,963
West Total		0.039	0.077	0.154	0	0.362	0.723	1.447	1,829	2.303	4.607	9.213	15,344
Total		0.193	0.385	0.770	940	1.055	2.109	4.219	6,055	4.043	8.087	16.174	26,306



Legend

- Prop WL (Low Interim Build-out)
- Prop WL (High Interim Build-out)
- Prop WL (Full Build-out)
- Prop Lake Fort Phantom EST 1
- Prop Fort Phantom Lake EST 2
- Existing Elevated Storage
- Existing Ground Storage
- Existing Pump Station
- Existing WTP
- Existing Water Lines
- City Limits
- Existing Parcels
- Roads
- Streams
- Lakes

Landuse Phase

- Low End Interim
- High End Interim
- Full Buildout

Note: Water line size labels are in units of inches

CITY OF ABILENE

JACOB & MARTIN, LTD.
CONSULTING ENGINEERS

Figure 5.1
Lake Fort Phantom Hill Water System Improvements

N

0 2,000 4,000
Feet